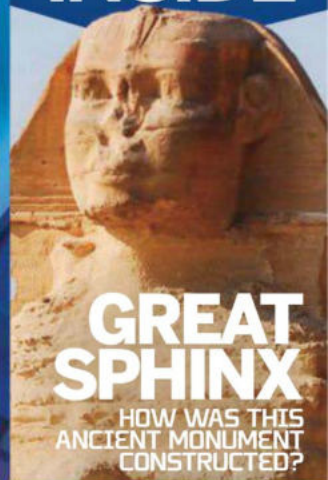


THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

INSIDE



GREAT SPHINX

HOW WAS THIS ANCIENT MONUMENT CONSTRUCTED?

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

+LEARN ABOUT

- MOSQUITO REPELLENT
- ANCIENT OLYMPICS
- SNOWMOBILES
- INCUBATORS
- BAZOOKAS
- WHIPLASH
- DESERTS

THE POWER OF

ATOMS

THE BUILDING BLOCKS OF THE UNIVERSE

- HOW ELEMENTS ARE CREATED
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10 SPACE MYTHS
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KILLER WHALES

What makes the mighty orca a formidable hunter?

WASPS

How do these predatory insects make their lairs?

TANK TECHNOLOGY

Inside super-smart combat vehicles

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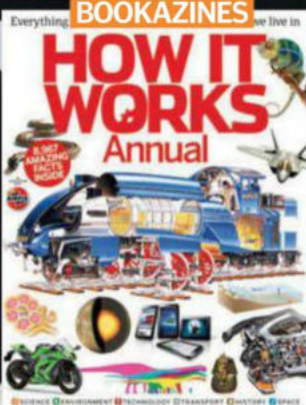
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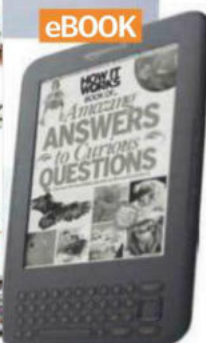
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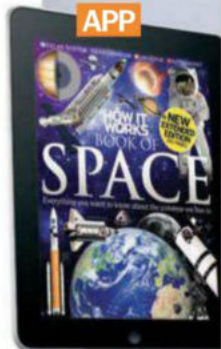
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FEED YOUR MIND!

Well, as they say, 'it's the smallest things that can have the greatest effects'. And in the case of our cover feature topic this issue, never was a truer phrase spoken.

Though a single atom is infinitesimally speck-like and contains mainly empty space – like, seriously, 99.9 per cent empty space – join them all together and atoms make up everything we see – not to mention what we can't see – in the world around us. An atom may be the smallest unit of an element that still has the chemical properties of that element, but the power of the atom should never be underestimated. And while it's true that you would require a very powerful scanning electron microscope at several million times magnification to observe the form of an individual atom, these super-small particles are nothing less than the 'building blocks' of the universe. Now, you don't get much bigger than that.

Elsewhere this issue, you'll find pure action in the form of tank technology as we look not only under the hood but also inside the brains of the smartest systems on board today's most advanced combat vehicles and reveal how these highly sophisticated beasts are radically changing the face of the modern battlefield.

Enjoy the issue.

Helen Laidlaw
Editor

Meet the team...



Dave

Ed in Chief

It's great to see that although the behemoths in the tanks feature on page 50 are definitely powerful beasts, it's not all brawn over brains – there's some smart tech inside too.



Ben

Features Editor

Imagine how safe and powerful you'd feel inside one of the amazing tanks on page 50? Learning how today's intelligent tanks are revolutionising modern warfare was great.



Robert

Features Editor

In addition to the amazing 'Power of atoms' feature, it was also fascinating to take a look inside an ultrabook; the manufacturers manage to cram so much tech into such a small space.



Adam

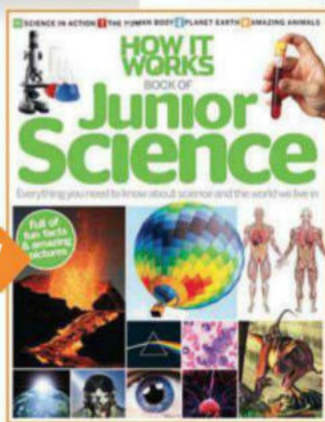
Senior Sub Editor

Learning about the ancient Olympics was great preparation as I'm booked to see two events at the 2012 Games: tennis and archery. I'm still trying to figure out why I picked the latter...

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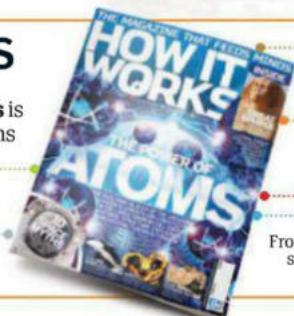
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The splendour of the natural world explained

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Be it road, rail, air or sea, you'll find out about it in Transport



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Your questions about how things worked in the past answered

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Explaining the applications of science in the contemporary world around us

SPACE

From exploration of our solar system to deep-space adventures

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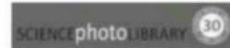
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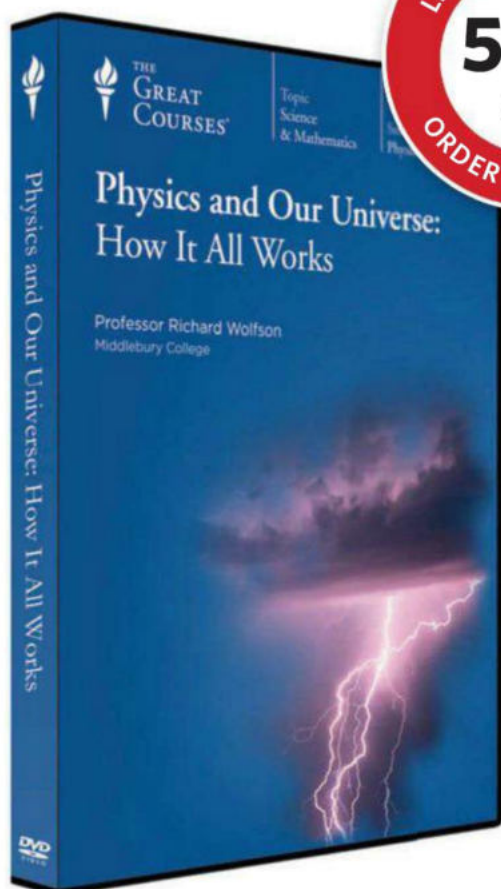
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The magazine that feeds minds!

MEET THE EXPERTS

Find out more about the experts in this month's edition of **How It Works...**

Tom Harris The power of atoms



Science writer Tom explains the awesome power of the universe's quantum construction kit, revealing how elements are made, how atoms behave and how they hold the cosmos together.

Luis Villazon Killer whales



Zoologist Luis illustrates the strength and power of the mighty orca and reveals not only how these massive whales hunt so stealthily, but also why they can be trained to perform tricks in captivity.

Lynsey Porter The human bladder



This issue Lynsey explains what happens when you're bursting for the loo, revealing the many different muscles involved with urinating. Learn what causes incontinence and also what urine contains.

Kathryn Waterfield A-Z of the ancient Olympics



Kathryn, who specialises in Greek history, lives on a small organic olive farm in Greece with her husband,

Robin, also an acclaimed author. They recently published their first book together, *The Greek Myths*.

James Baker How to... fly a plane



Pilot James provides a brief guide to flying a commercial aircraft, offering you practical tips on everything from

take-off to landing, including understanding the cockpit's complex instrument panel.

Vivienne Raper World's biggest deserts



Discover how deserts like the Sahara were formed as Vivienne reveals the major landforms found in this terrain,

and how the wildlife can tolerate such extreme temperatures.

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The power of atoms

Discover the nature of these miniature particles and how they have a big effect on everything in the world around us as well as the universe as a whole



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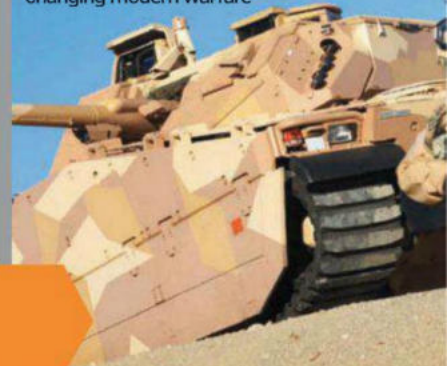


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"The manipulation of atoms has always been at the heart of human technology"

POWER OF ATOMS

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Mach 20 hypersonic jet explodes

The highly classified Falcon HTV-2 hypersonic test vehicle was ripped apart while travelling at over a blistering 13,000 miles per hour



After extensive analysis by the USA's Defense Advanced Research Projects Agency (DARPA), it has been concluded that the recently destroyed Falcon HTV-2 test vehicle was ripped apart in Earth's atmosphere by a series of speed-induced shockwaves.

The shockwaves were induced as the jet entered its 'controlled descent' at 20,900 kilometres (13,000 miles) per hour, a descent that was planned to conclude with the aircraft diving into the ocean for recovery. In reality, the descent was far from controlled, with temperatures north of 2,000 degrees Celsius (3,632 degrees Fahrenheit) shearing off large sections of the jet's skin and generating a series of shockwaves that were 100 times what it was built to withstand.

The result of this critical instability led the HTV-2 to fall out of the sky in a rain of molten metal and scatter into the Pacific Ocean.

Despite the test flight being seen by many commentators as a spectacular failure, US Air Force Major Chris Schulz rebuked that view, stating: "Data collected during the second test flight revealed new knowledge about thermal-protective material properties and uncertainties for Mach 20 flight inside the atmosphere. The result of these findings is a profound advancement in understanding the areas we need to focus on to advance aerothermal structures for future hypersonic vehicles. Only actual flight data could have revealed this to us."

Moving forward, the Pentagon now hopes the vehicle will be developed to a level where it could carry a selection of bombs to strike targets anywhere across the globe within an hour. This aim will have been boosted by the crash report also highlighting the Falcon's successful pre-crash cruise speed reached Mach 20, which it managed to sustain for over nine minutes.

When the HTV-2 started to break apart, it was being subjected to temperatures greater than 2,000°C (3,632°F)

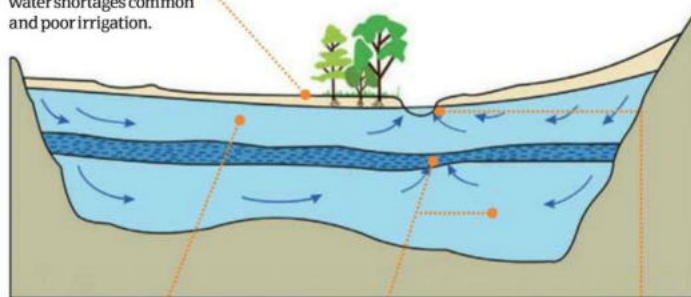


3x © DARPA

The Falcon HTV-2 separates from the Minotaur rocket to begin its re-entry phase

"Temperatures north of 2,000°C sheared off large sections of the jet's skin and generated a series of shockwaves that were 100 times what it was built to withstand"

Arid
Huge swathes of the African continent are incredibly dry, with water shortages common and poor irrigation.



Aquifers
The discovered water is harboured in vast underground aquifers (large areas of water-bearing, permeable rock).

Layered
The water – which is up to 75m (246ft) deep – is located in unconfined, semi-confined and confined reservoirs.

Flow
The groundwater is not stationary, making it potentially easier to extract via wells for irrigation and/or consumption.

Africa sits on a vast reservoir of water

Scientists reveal the super-dry continent is hiding huge underground basins of H₂O

A team of international scientists has revealed that there are vast aquifers – underground layers of water-logged rock – positioned beneath Africa that contain 100 times the amount of water found on the surface. Writing in *Environmental Research Letters*, the team reveals the expanse of the underground aquifers is immense and that – in light of the fact that 300 million people in Africa do not have access to safe drinking water – if they can be exploited it could really help meet the growing demand for water.

Speaking on the publication of the report, Helen Bonsor of the British Geographical Society and team member, said: "Where there's greatest groundwater

storage is in northern Africa, in the large sedimentary basins, in Libya, Algeria and Chad. The amount of storage in those basins is equivalent to 75 metres (246 feet) thickness of water across that area."

The team gathered the data from existing hydro-geological maps, as well as from 283 aquifer studies. The researchers hope the publication of the report and partnering water maps will change the perception of many African nations being water scarce. Interestingly, however, the team stresses in the report that large-scale boring operations should not be instigated until more information about the water quality and the geological impact of mining are determined.

How the Falcon reached speeds of 13,000mph

Follow a step-by-step guide to the six key phases necessary to hit such awesome speed

2. Orientation

The HTV-2 separates and uses its reaction control system (RCS) to orient itself for re-entry.

3. Re-entry

RCS and aero controls guide HTV-2 throughout the re-entry process into the Earth's upper atmosphere.

5. Glide

Testing can then begin, with the HTV-2 performing various manoeuvres to explore aerodynamics at hypersonic speeds.

4. Pull-up

The HTV-2 performs a pull-up manoeuvre to control speed and altitude for a sustained glide.

1. Launch

The Minotaur IV Lite launch vehicle boosts HTV-2 to near-orbital speeds.

6. Wet landing

Finally, the HTV-2 rolls and dives into the ocean to terminate its flight.

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WHAT ON EARTH IS IT?

A close-up look at the world!

We reveal the identity of the weird images on HIW Daily, plus a few of your suggestions. Remember, we're looking for creativity as much as accuracy!

What is it?



1. Tanzanite

This is tanzanite, a purple variety of the mineral zoisite. Tanzanite was discovered by Westerners in 1967 in the Mererani Hills of northern Tanzania and it is now commonly used as a gemstone in jewellery. Interestingly, if exposed to fluorescent light, tanzanite's colour shifts more to blue than purple due to its crystal formation.

Your best answers:

'Kryptonite?' **Ben Snow** 'A strange mineral?' **Ashwin Kumaar**

What is it?



2. Waterlock

This is a batch of sodium polyacrylate - which is also known as waterlock, a polymer widely used in consumer products. The reason for its widespread use is its ability to soak up as much as 300 times its mass in water. As such, products such as thickening agents, coatings and nappies often take advantage of its absorption abilities.

Your best answers:

'Fish eggs?' **Quinnlan Hatchett** 'Jello Dippin' Dots?' **Grave Lopez**

What is it?



3. Sea egg

This is a shot of the species tripneustes ventricosus, more commonly referred to as the West Indian sea egg, a spiny type of sea urchin. These creatures are usually dark in colour, ranging from a deep purple to brown, and always sport white spines roughly two centimetres (0.8 inches) in length. They are typically found around the Caribbean.

Your best answers:

'Closeup of a dodgy hairdo?' **James Gant**

'A baby hedgehog?' **Christopher Attwood**

1

2

3



To get involved, visit WWW.HOWITWORKSDAILY.COM to make your guess now – the more creative the better!

THIS DAY IN HISTORY 17 MAY: How It Works issue 34 goes on sale, but what else

1521

Edward Stafford (right), the third Duke of Buckingham, is executed for treason.



1792

The New York Stock Exchange is established.

1809

Napoleon I of France (right) orders the annexation of the Papal States to the French Empire.



1875

The first Kentucky Derby is held and is won by Aristides.

1902

The Antikythera mechanism, an ancient mechanical analogue computer, is discovered.



**"Within 30 years,
we will have the
technological means
to create super-
human intelligence"**

OPINION

The Gadget Show's Pollyanna Woodward talks tech

Could the rise of the machines be closer than we think?

The rise of artificial intelligence

With an eagle eye on the future, The Gadget Show's Pollyanna Woodward reveals how, year by year, AI is ever-closer to becoming a reality...



will have not just on the field of technology but also, more generally, human civilisation as a whole.

One topic we had briefly discussed before in the studio that came up again on our recent trip to Japan is 'The Technological Singularity' – a notion centred on the emergence of artificial intelligence. The trigger for this topic was a couple of robots that we had the chance to



In the new series of *The Gadget Show*, Jason Bradbury and I are lucky enough to be trotting the globe, testing some of the weirdest, most wonderful and downright incredible technologies that have recently been introduced or are currently in development. During this tour we contemplate the impact that these new gadgets

interact with. One of these bots was the world-famous ASIMO made by Honda, a childlike walking, talking, hopping, football-kicking automaton. The other was a tele-existence robot based on 30 years of research called Telesar V, which is able to send visual, audio and touch data to the human operator via multiple sensors and small motors located all over the operator's clothing.

I'd briefly read about The Singularity before, but hadn't given it much thought before this discussion. The basic concept revolves around the idea of a hypothetical future emergence of greater-than-human intelligence through technological means – in essence, the rise of an artificial intelligence to surpass that of humans.

The idea was first conceived by Vernor Vinge, a mathematician and science-fiction author who once wrote in an essay, 'Within 30 years, we will have the technological means to create super-human intelligence; shortly after, the human era will be ended.' This assertion



ASIMO stands for Advanced Step in Innovative Mobility

was made in 1993 so, in theory, we only have 11 years left! Vinge is not alone either, as a similar theory has been popularised by futurist and author Ray Kurzweil. Both believe that during the 21st century (or at some point not long after), AI will outwit human intelligence and robots will not only work via programs, but also have the ability to think for themselves and evolve just as the human mind does. Vinge put this outcome down to the advancement of human bio-tech tools such as brain-interface computers. Beyond this turn of events, however, the theorists believe the future is impossible to predict.

This raises many questions, not least this: if robots are the 'species' with the greatest intelligence, will they one day be the ones that could potentially rule? Only after meeting the incredibly advanced, super-hi-tech robots in Japan do I see that something I might once have dismissed as little more than sci-fi nonsense might actually be quite close to becoming a reality.

happened on this day in history?

1939

The first live televised sporting event is held, a baseball game between the Columbia Lions and the Princeton Tigers.

1943

The famous 'Dambuster' raids are undertaken by the RAF's 617 Squadron.



1973

Televised hearings in the Watergate scandal begin in the US Senate.

1994

Malawi holds its first multi-party elections.



2006

The aircraft carrier USS Oriskany is sunk in the Gulf of Mexico in order to form an artificial reef.

10 COOL THINGS WE LEARNED THIS MONTH

AMAZING TOPICAL FACTS...

Earth circumnavigation is possible by Sun power alone

PlanetSolar, a solar-powered boat designed by New Zealander Craig Loomes, has completed its world tour – powered exclusively by solar energy. The boat is officially the biggest solar-powered boat in the world, measuring 35 metres (115 feet) by 15 metres (49 feet) and covered in over 500 square metres (1,700 square feet) of photovoltaic panels. Its tour finished on 4 May and took 585 days.

2



1

Asteroid mines are on the drawing board

Several billionaire entrepreneurs have released details of plans to mine asteroids for valuable resources in the next decade. It's a multi-million-dollar plan that includes Google chief Larry Page and director James Cameron. Within ten years they plan to move from selling orbital observation platforms to prospecting on some of the thousands of asteroids that pass near Earth.

"Potent levels of the greenhouse gas methane are being released from the Arctic"

4

The Arctic is smelly

Potent levels of the greenhouse gas methane are being released from the Arctic. A recent airborne study from NASA shows that cracks in Arctic sea ice are releasing methane into the atmosphere. As a part of the HIAPER Pole-to-Pole Observations (HIPPO) airborne campaign, cracks in the ice were observed to allow the ocean to interact with the air and let methane escape from large natural reservoirs.

3

Spectrum is 30

Clive Sinclair's ZX Spectrum is 30 years old. It was the most successful consumer computer of its generation, selling over 5 million units and beating its closest competitor, Acorn's BBC Micro, by selling at half the price. Despite it only being available by mail order at the time, the backlog of orders reached 30,000 only three months after its launch.



5

Scottish wildcats are on the up

The endangered Scottish wildcat (also known as the Highland tiger) has been discovered in Cairngorms National Park. Camera traps have caught images of the wildcats – of which there are estimated to be around 400 left in the wild – across the park. The main threat to the species is twofold: inter-breeding with domestic and feral cats, as well as diseases spread by domesticated cats.



6

'Godzillus' really existed

An amateur palaeontologist has discovered what is suspected to be a fossilised sea anemone-like creature that stood a massive 2.75 metres (nine feet) tall. 'Godzillus' is 450 million years old and took Ron Fine 12 trips over a single summer to excavate all 68 kilograms (150 pounds) of the fossil from a site in Kentucky.

7

Men will live as long as women

By 2030, the average age of death for both men and women will be the same. In the last 100 years the trend has been for women to live, on average, five years longer, but with fewer men smoking and most generally in safer careers, male life expectancy is rapidly catching up.

8

Underdog meerkats are the best hunters

Using incentives like jars of scorpions (a meerkat delicacy) with tinfoil lids, a Cambridge team has uncovered intimate details of meerkat hunting techniques. Their constant scrabbling at the transparent sides of the jar rather than the foil lid indicates success is more a result of persistence than intelligence. They also found meerkats lower in the family hierarchy were the most innovative hunters in the mob.

Braking at 1,000mph isn't easy

A team of British engineers designing a car that can hit 1,610 kilometres (1,000 miles) per hour – the Bloodhound SSC (supersonic car) – has run into a problem: braking. Its speed is generated using a Eurofighter Typhoon jet engine, but stopping safely is a major issue. To create the drag necessary, it will need two drag chutes, airbrakes and 6.5 kilometres (four miles) just to 'slow' the vehicle down to 322 kilometres (200 miles) per hour.

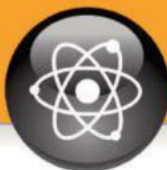
10

9

The Milky Way is packed with planets

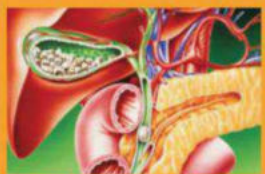
According to a detailed statistical study by NASA, our Milky Way galaxy contains a minimum of 100 billion planets. The discovery is based on the detection of three exoplanets outside our solar system. The survey concludes that there is an average of one planet for every star, with at least 1,500 planets within 50 light years of Earth. The survey also indicates more than 10 billion Earth-sized planets in our galaxy.





Welcome to... **SCIENCE**

You may not be able to see atoms with the naked eye, but everything in the world, and beyond, is made of these key building blocks. Here we look at their makeup, how they can be harnessed to generate energy, the cutting-edge tech being used to study them and more.



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LEARN MORE

Atoms are the ultimate construction kit. With a big enough collection, you can build everything from Venus de Milo to Venus the planet...

THE POWER OF ATOMS



Everything in the universe is made of countless tiny atoms that are joined into different structures, essentially like toy building blocks. But instead of snapping together through friction, like plastic blocks, atoms snap together through electrical charge.

At the centre of every atom you'll find the nucleus – a blob of positively charged particles called protons and neutrally charged particles called neutrons. The tiny nucleus is surrounded by even smaller negatively charged particles called electrons. Usually, there is an equal number of protons and electrons. Because of their opposite charge, these protons and electrons are attracted to

each other, which is what holds the atom together. With this balance, the atom is electrically neutral.

But these electrons are a fickle bunch: they're not only attracted to their own atom's nucleus – they're sometimes attracted to the nuclei of other atoms as well. In the right situations, this cross-atom attraction can provide a sort of 'electron glue' that bonds multiple atoms together.

An atom's bonding prospects depend on its proton and electron count and arrangement, which is unique for every element on the periodic table. Electrons surround the nucleus at specific energy levels, called shells. The shell closest to the nucleus is the lowest energy level,

and the shell farthest from the nucleus is the highest energy level. Each shell can hold a limited number of electrons. For example, the lowest-level shell holds a maximum of two electrons, and the next level holds up to eight electrons. To achieve maximum stability, electrons move to the lowest possible energy level that has available openings.

The critical factor in chemical bonding is the number of openings in an atom's outermost shell, called the valence shell. When there is the right combination of openings, electrons can jump from one atom to another, two atoms can share an electron, or many atoms can share a cloud of electrons. Atoms are more stable when their valence shells are full, so

Super-dense

1 The nucleus which is located at the heart of every atom makes up more than 99.9 per cent of its mass, but only a trillionth of its total volume.

Electrons are tiny

2 At only 1/1,836th the size of a proton or neutron, electrons contribute almost nothing to an atom's mass, but are the most active component of an atom, responsible for bonding.

The rest is filler

3 More than 99.9 per cent of an atom's volume is empty space. If an atom's nucleus were the size of a basketball, its electrons would be zipping around several miles away.

The quantum leap

4 When electrons jump between energy levels, they don't move through the space between. Instead, they disappear from one level and then instantly reappear on another level.

The force is strong

5 Atomic nuclei are held together by the strong force, which is 10^{38} times stronger than gravity, but only operates on the minute scale of a nucleus.

DID YOU KNOW? As atoms circulate extensively over time, your body includes atoms that were once part of the dinosaurs



At full power, trillions of protons will race around the LHC accelerator ring 11,245 times a second

© CERN

electrons will readily move in ways that form complete valence shells.

When multiple atoms bond together, they form molecules. Molecules can consist of many identical atoms – that is, atoms of the same element – or they can include atoms of multiple elements. A multi-element molecule is called a compound. Collectively, vast numbers of molecules form the wide variety of materials that we know and love. The structure of the individual molecules, along with the way those molecules fit

yields virtually unlimited possibilities. Scientists and engineers have already developed countless thousands of novel materials, and we're nowhere close to exhausting the potential combinations.

The chemical reactions involved in recombining atoms can prove useful themselves. For example, fire is the result of a chemical reaction between the chemical compounds in wood (or some other fuel) and oxygen in the atmosphere, triggered by intense heat. Burning

"An atom's bonding prospects depend on its proton and electron count and arrangement, which is unique for every element on the periodic table"

together, ultimately dictates how any material feels and behaves.

Broadly speaking, there are three styles of organisation: gases, liquids and solids. In gases, molecules move about freely. In liquids, molecules fit together loosely, sliding over one another like marbles in a bowl. In solids, meanwhile, molecules are arranged in more rigid structures, and so don't move as freely.

Within these groups, different combinations and arrangements of atoms result in an incredible range of qualities and behaviours. Even limited to a set of identical atoms, structural changes can make huge differences. For example, compare diamonds and graphite. Both are arrangements of carbon atoms, but you don't see anyone proposing on bended knee with a pencil.

In a diamond, strong covalent bonds join atoms in a rigid lattice framework. The result is one of the hardest, toughest materials in the world. In graphite, on the other hand, carbon atoms are arranged in a layered structure, with very weak bonds between layers – so weak that touching a pencil to paper is enough to break them. The ability to combine and arrange atoms into different structures

wood produces char and gaseous compounds of hydrogen, carbon and oxygen. As the gases heat up, the compounds break apart, and the atoms recombine with oxygen in the air to produce water, carbon dioxide, carbon monoxide and nitrogen; this releases a great deal of energy in the form of heat and light in the process.

Between forming new materials and producing usable energy, the manipulation of atoms has always been at the heart of human technology – even when we had no clue atoms existed. In recent years, scientists have managed to make new atoms, forming 20 elements not observed in nature by combining existing nuclei into new super-heavy nuclei. These manmade atoms quickly fall apart, but stable variations may not be far off. In the 20th century, humans unlocked the internal energy of atomic nuclei for the first time, yielding both nuclear powerplants and bombs.

Today, physicists are investigating the even smaller components – quarks, leptons and bosons – that make up atoms. At this still mysterious level, new findings could fundamentally redefine our understanding of the universe. ✨

Anatomy of an atom

What are the fundamental parts that make an atom?

Electrons

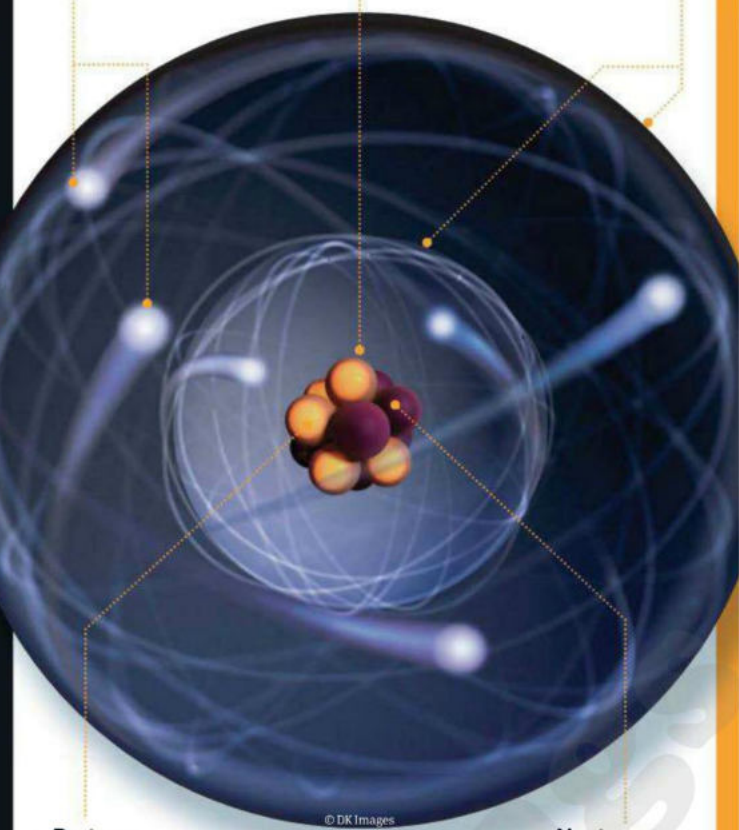
Electrons are very small, negatively charged particles that move quickly around the atom's nucleus.

Shells

Electrons can only exist in set energy levels, commonly called shells. Each shell has openings for a limited number of electrons.

The nucleus

The centre of the atom, and almost all of its mass, is the nucleus. The nucleus is made up of protons and neutrons.



© DK Images

Protons

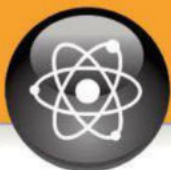
Protons are positively charged particles in the nucleus. All elements are defined by how many protons they have.

Neutrons

Neutrons – particles with no electrical charge – help give atoms their mass. They are slightly bigger than protons.



The 'Fat Man' nuclear bomb was dropped on Nagasaki, Japan, on 9 August 1945



"The ability to arrange atoms into different structures yields virtually unlimited possibilities"

Atomic models

Atoms don't follow the rules of Newtonian physics that we see every day in the world around us, making it impossible to visualise what's actually happening at an atomic level. The best that scientists can do is create theoretical models that give us a general conceptual comprehension of what's going on. Here are some of the noteworthy models that greatly advanced our atomic understanding...



Thomson's 'Plum Pudding' model (1904)

English physicist JJ Thomson discovered the electron as far back as 1897, showing for

the first time that atoms had smaller constituent components. To account for the atom's overall neutral charge, Thomson theorised – in his 1904 model – that the negatively charged electrons must sit in a regular pattern within a uniformly distributed positive charge, like raisins in a plum pudding.



Rutherford's nuclear model (1911)

New Zealand-born physicist Ernest Rutherford, who studied at Cambridge University,

disproved Thomson's model, when he demonstrated the existence of a positively charged atomic nucleus. Rutherford proposed the atom was like a miniature solar system, with a relatively massive, Sun-like nucleus at the centre, orbited by much smaller planet-like electrons.



Bohr's shell model (1913)

In classical mechanics, any charged particle moving in a curved path emits radiation. Consequently, in

Rutherford's model, electrons would lose energy and collapse into the nucleus. Danish physicist Niels Bohr proposed electrons moved in a different type of orbit. He theorised electrons surrounded a nucleus in fixed energy levels (shells) and only emitted radiation when they 'jumped' from shell to shell.

What are elements and compounds?

Elements are substances made entirely of one type of atom. Each element is defined by how many protons are in a single atom of that element. For example, every hydrogen atom has just one proton, while every gold atom has 79 protons, and so on. In the right circumstances, atoms of different elements can join together to form a chemical compound. The bonds that hold compounds together result from various movements of electrons. Here are two examples:

Ionic bond

Ionic bond

Ionic bonds form when an electron jumps from one atom to another, resulting in two electrically charged atoms, called ions.

Valence shell

Electrons travel in set energy levels called shells. Each shell has a limited number of openings for electrons. The number of openings in the outermost level, known as the valence shell, determines how an atom can form bonds.

Sodium atom

The sodium atom's valence shell has only one electron, leaving seven openings.

Chlorine anion

The chlorine atom now has 18 electrons and 17 protons, making it an anion – an atom with a net negative charge. The opposite charges bond the two atoms together to form the compound sodium chloride, more commonly known as table salt.

Covalent bond

Covalent bond

Atoms can also form compounds by sharing electrons between them, in covalent bonds.

Nitrogen atom

A nitrogen atom has five electrons in its valence shell, leaving three openings.

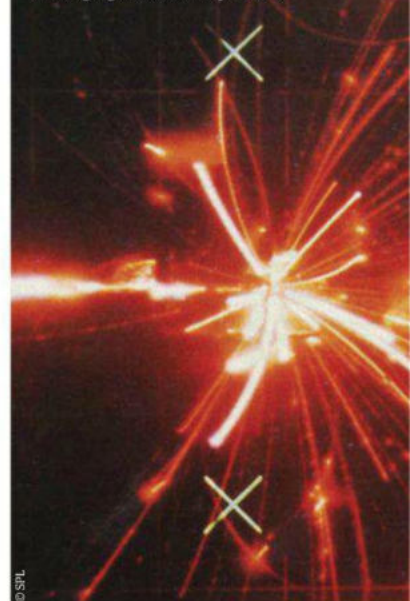
Electron pairs

Each of the three hydrogen atoms shares its original single electron and one of the original nitrogen electrons, collectively forming the compound ammonia.

Hydrogen atoms

Each of these three hydrogen atoms has a single electron in its valence shell, leaving one opening.

Bombarding atoms together leads to the dislodging of subatomic particles



Electron leap

To achieve overall stability, the spare electron from the sodium atom leaps to fill the chlorine atom's valence shell.

Chlorine atom

A chlorine atom's valence shell holds seven electrons, leaving only one opening.

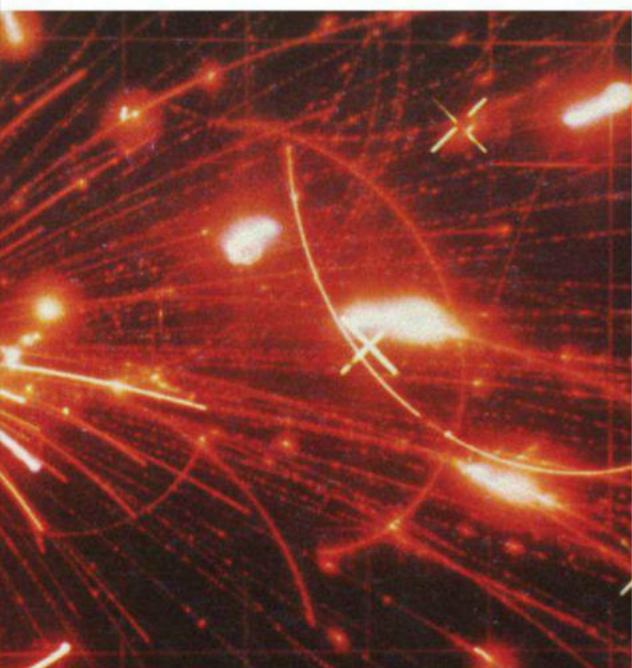
Sodium cation

The sodium atom now has ten electrons and 11 protons, making it a cation – an atom with a net positive charge.

From stars to space dust, everything in the universe is made up of atoms



DID YOU KNOW? If you took all the empty space in the human race's bodily atoms, the matter could fit between your fingers



Radioactive decay explained

Most atoms are highly stable, meaning that the nucleus will always hold together, barring extreme circumstances. But in some atoms, the energy that binds the nucleus will eventually fail in a process called radioactive decay – the spontaneous disintegration of the nucleus.

The most notorious unstable atoms are elements with a very high number of protons, such as uranium (92 protons). But some lighter elements, such as carbon, are radioactive as well, when they have too many or too few neutrons. Neutron-count variations are called isotopes. For example, while garden-variety carbon-12 (six protons and six neutrons) is entirely stable, carbon-14 (six protons and eight neutrons) is radioactive.

Radioactive decay results in the ejection of subatomic particles from the nucleus. In alpha radiation, the atom ejects two protons and two neutrons. In beta radiation, a neutron turns into a proton, ejecting a neutrino particle and a free electron, called a beta wave. In gamma radiation, the nucleus releases extra energy in the form of a photon. Energy from the ejected particles can mutate human DNA, sometimes resulting in disastrous cellular changes, ie cancer.

The nucleus material that's left forms a 'daughter atom'. When the proton count has changed, the daughter atom will be entirely different from the original atom. Carbon-14 decays into nitrogen, for example.



How to split an atom

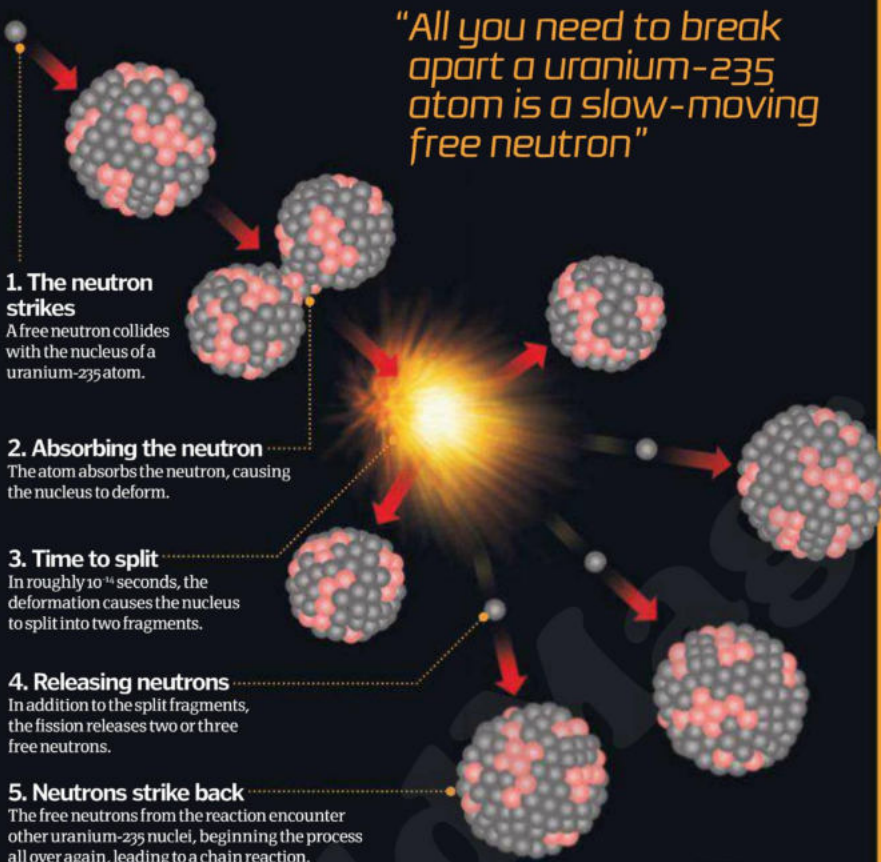
Add this to the pile of mind-bending atom qualities: an atomic nucleus has less mass as a whole than its protons and neutrons would have separately. How is this possible? Well, when the nucleus is formed, some of the mass of its constituent parts changes into energy that binds the protons and neutrons together. In other words, there's high potential energy locked up in the nucleus.

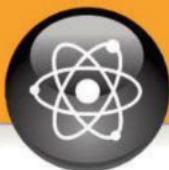
It's possible to release this energy, and actually harness it, by splitting specific types of atoms apart into multiple fragments – a process known as nuclear fission. All you need to break apart a uranium-235 atom is a slow-moving free neutron. The uranium atom will absorb the free neutron, the extra energy makes the uranium nucleus highly unstable, and the atom splits into two smaller atoms

and two or three free neutrons. The potential energy in the nucleus is released as kinetic energy, in the form of these particles moving at great speed. The resulting free neutrons, in turn, can break apart other uranium-235 atoms, leading to a chain reaction.

A powerplant controls the reaction and harnesses the heat of this kinetic energy in order to generate steam that turns turbines. In contrast, in an atomic bomb the reaction is allowed to go unchecked, in order to generate a massive explosion.

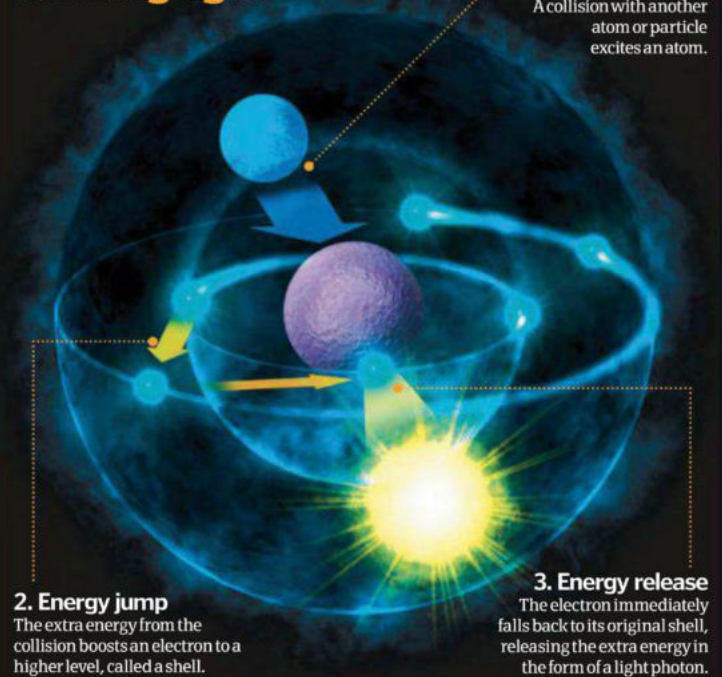
You can also tap into this energy through nuclear fusion – the combining of two nuclei into a new nucleus. Nuclear fusion generates the energy of stars and hydrogen bombs. However, nobody has been able to harness it effectively as a power source yet.





"13.5 per cent of the world's electricity in 2010 came from the world's 436 nuclear reactors"

Creating light



1. Collision

A collision with another atom or particle excites an atom.

2. Energy jump

The extra energy from the collision boosts an electron to a higher level, called a shell.

3. Energy release

The electron immediately falls back to its original shell, releasing the extra energy in the form of a light photon.

How atoms emit light

Light is the result of electrons moving between defined energy levels in an atom, called shells. When something excites an atom, such as a collision with another atom or a chemical electron, an electron may absorb the energy, boosting it up to a higher-level shell. The boost is short-lived, however, and the electron immediately falls back down to the lower level, emitting its extra energy in the form of an electromagnetic energy packet called a photon. The wavelength of the photon depends on the distance of the electron's fall. Some wavelengths, such as radio waves, are invisible. Photons with wavelengths in the visible spectrum form all the colours that we can see.

© DK Images

France is currently leading the way with nuclear power, with nearly 80 per cent of its overall energy derived from atom power



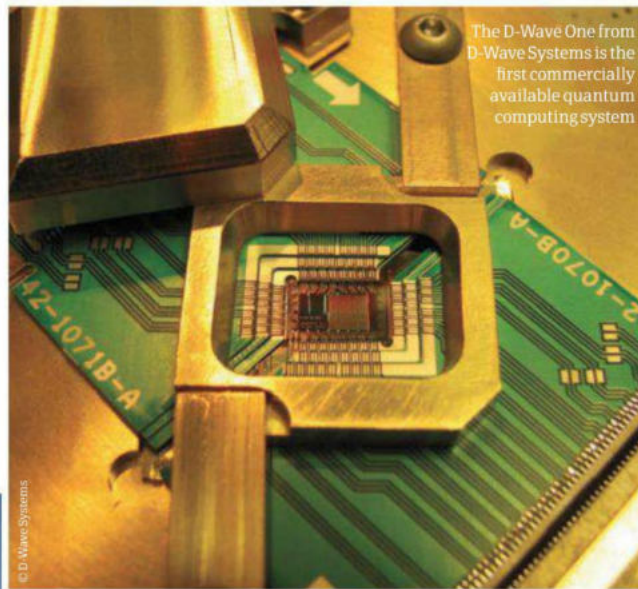
Atoms and quantum computing

One of the many oddities about activity on the subatomic level is that subatomic particles do not have a defined state until they are observed. Instead of saying exactly where a proton, electron or other subatomic particle actually is, physicists instead talk about a probability cloud, indicating all of its possible states.

The weird but real phenomenon of quantum tunnelling helps illustrate this. As a subatomic particle approaches a barrier, one edge of the probability cloud for its position moves to the other side of the barrier. So, there's a small chance it actually will be on the other side of the barrier. Sometimes, it is on the other side,

effectively tunnelling straight through the barrier.

Another way to define this ambiguity is to say a subatomic particle is in all possible positions at once. Contrast this with a computer bit, which at any moment, has a value of either 1 or 0. The fundamental idea of quantum computing is to employ each of the many 'superposed' states to perform part of a calculation, in order to do the entire calculation far more quickly than a conventional computer could manage. The field is now in its infancy, with limited implementations, but it could revolutionise computing in the foreseeable future.



The D-Wave One from D-Wave Systems is the first commercially available quantum computing system

© D-Wave Systems

Atom power by the numbers

No matter how you feel about nuclear power, it's part of your life. According to the Nuclear Energy Institute, 13.5 per cent of the world's electricity production in 2010 came from the world's 436 nuclear reactors. France leads the pack, drawing 77.7 per cent of its power from nuclear energy in 2011. The UK comes in at considerably less at 15.7 per cent.

Other energy sources still exceed nuclear power. The International Energy Agency lists coal/peat as the top source, providing 40.6 per cent of the world's power. Natural gas is second with 21.4 per cent, followed by hydropower with 16.2 per cent. Solar, wind, biofuels, heat and geothermal power combined amount to only 3.3 per cent.

430 BCE

Philosopher Democritus states if you keep cutting matter up, you'll eventually get an invisible piece (called an atomos).

1704 CE

Sir Isaac Newton (right) theorises all matter is made of hard, unbreakable but movable particles.



1803

John Dalton proposes each element has its own atom, and describes chemical reactions as a rearrangement of atoms.

1869

Dmitri Mendeleev organises elements on the periodic table, which shows patterns of chemical reactions.

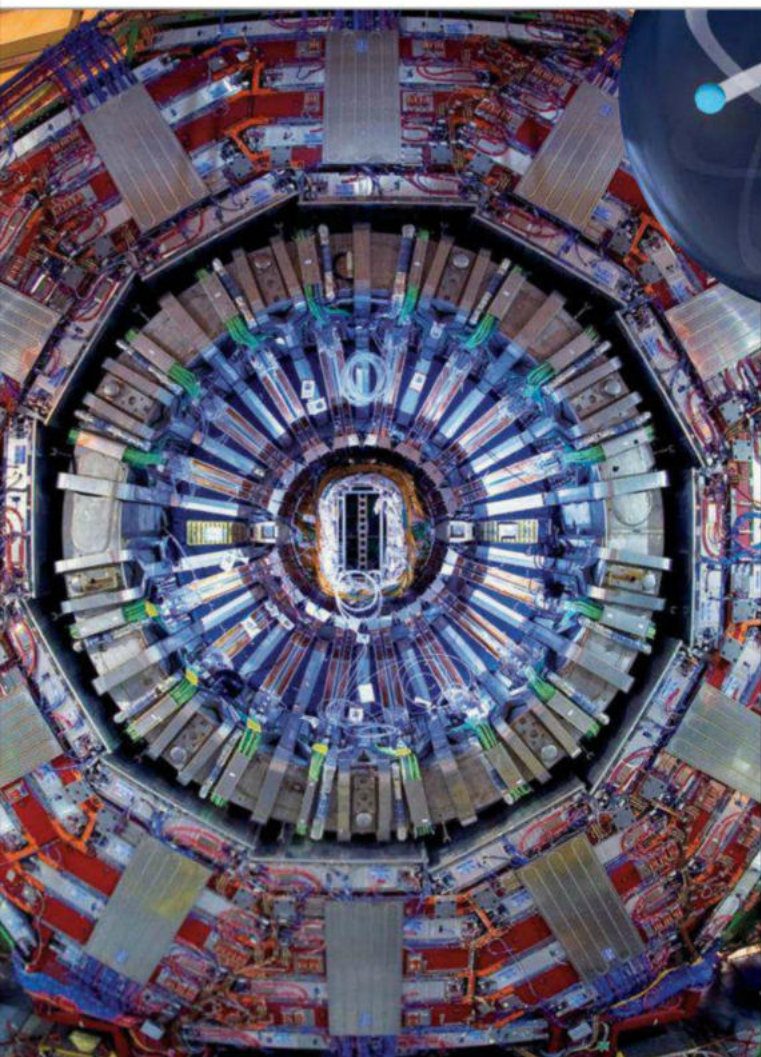
1897

JJ Thomson discovers the electron, before going on to propose the Plum Pudding theory.

1922

Niels Bohr wins the Nobel Prize for Physics for his work on atoms, much of which applies to this day.

DID YOU KNOW? When two subatomic particles meet, quantum entanglement links them to some extent forever

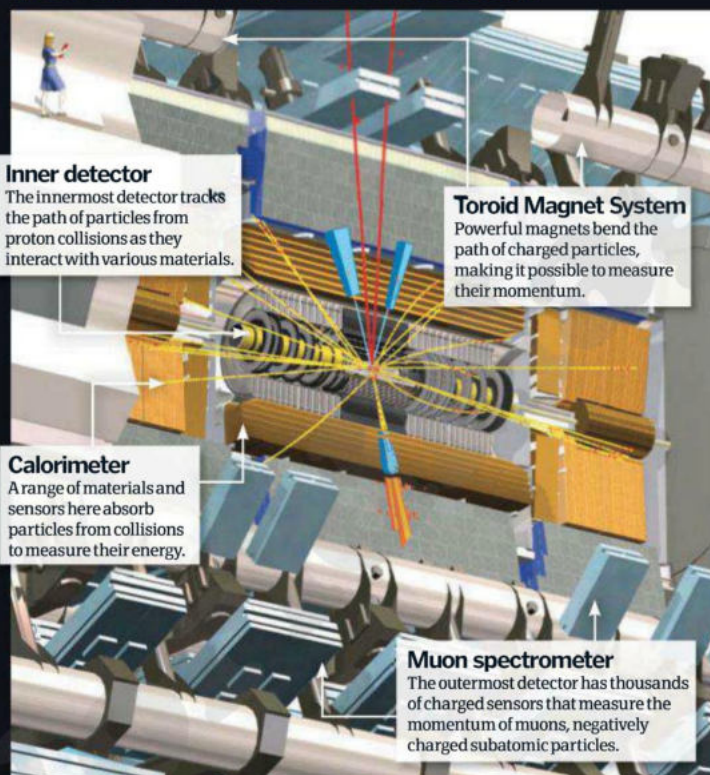


What exactly goes on in the LHC?

Some 50-170 metres (165-560 feet) beneath Switzerland and France, you'll find the Large Hadron Collider, a 27-kilometre (17-mile) circular racing track for atoms and subatomic particles. The collider accelerates and crashes streams of these particles into each other at 99.9999991 per cent the speed of light, in order to break them apart. So, why bother? Well, it takes collisions of this unprecedented intensity to get a look at some of the infinitesimally small particles that make up atoms. Examining these pieces is as close as physicists can get to seeing what the universe was like immediately after the Big Bang.

Researchers at the European Organisation for Nuclear Research (CERN) are collecting data on the speed, mass, energy, position, charge and trajectory of the particles in each collision. Analysis of the data could lead to new understandings of the nature of mass, gravity, dark matter and even other dimensions.

Inside the ATLAS detector



Inner detector

The innermost detector tracks the path of particles from proton collisions as they interact with various materials.

Toroid Magnet System

Powerful magnets bend the path of charged particles, making it possible to measure their momentum.

Calorimeter

A range of materials and sensors here absorb particles from collisions to measure their energy.

Muon spectrometer

The outermost detector has thousands of charged sensors that measure the momentum of muons, negatively charged subatomic particles.

What is the Higgs boson?



Professor Peter Higgs proposed his boson theory back in 1964

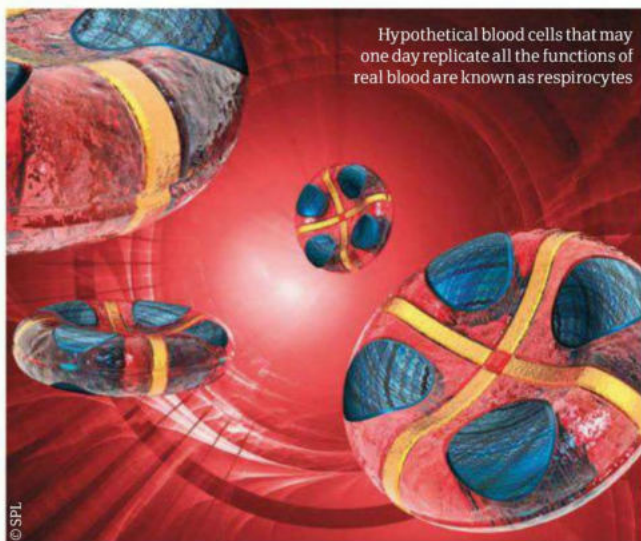
The Higgs boson is a theoretical particle proposed by Scottish physicist Peter Higgs as part of the Standard Model of particles and forces. The Standard Model is an incomplete theory that describes how the 12 known fundamental particles and three of the four known forces in the universe fit together (it doesn't account for gravity).

According to this theory, many fundamental particles had no mass immediately following the Big Bang, but gained mass later from interacting with an invisible energy field called the Higgs field, by way of a particle called the Higgs boson.

The Higgs boson is one of several missing pieces that make the Standard Model incomplete. Finding it with the Large Hadron Collider would lend additional credence to the Standard Model, giving us a strong indication of the nature of matter. Not finding it, after extensive searching, would indicate this theory is wrong, spurring physicists to focus on other schools of thought.



"Artificial blood cannot replace all the functions of human blood but it can carry oxygen effectively"



Hypothetical blood cells that may one day replicate all the functions of real blood are known as respirocytes

Artificial blood

What's it made of and why do we still have human blood transfusions?



We know that blood is the medium the human system uses to carry oxygen and nutrients to parts of the body that need it. We also know that it's made of four main parts: white blood cells that aid the immune system, red blood cells that carry oxygen, platelets that help form clots and the blood plasma that these elements are suspended in. We're still a long way from creating a true lab-grown substitute for our own blood, but there are occasions when artificial blood is a viable – and potentially lifesaving – alternative.

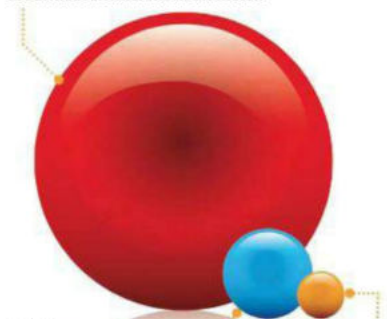
Human blood has a shelf life of up to 42 days and it needs to be kept cool, as it's prone to infection. Blood transfusions also need to be a compatible blood grouping (eg A, B, AB or O) or there can be dire consequences. Artificial blood cannot replace all the functions of human blood but it can carry oxygen effectively. It has a longer shelf life, doesn't need to be cooled, can be sterilised and is also blood-type agnostic – so, in other words, any blood type can use it. It's particularly useful on the battlefield or when there is a shortage of human blood stock.

Faking it

There are two main types of artificial blood: HBOC and PFC. HBOC (haemoglobin-based oxygen carrier) is made from a living source, either expired human blood, cow blood, genetically modified bacteria that produces haemoglobin or from human placentas. It resembles blood much more in its colour and consistency than PFC (perfluorocarbons), which is completely synthetic and suspended or emulsified in a substrate, so that it appears milky in colour and is oily to the touch. Both are known as oxygen therapeutics because they can carry oxygen in situations when a person's red blood cells can't on their own, such as after losing a lot of blood after a serious trauma.

Red blood cell

These are the body's natural oxygen carriers manufactured in bone marrow. They are around seven microns in diameter.



PFC

PFCs are very small, but at 0.2 microns they can carry around 20-30 per cent more oxygen than HBOCs.

HBOC

Much smaller than red blood cells (0.1 micron) to get to places that normal blood cells cannot.



Repellent like DEET, or N,N-diethyl-m toluamide, deters mosquitoes from making you their next meal

How mosquito repellent works

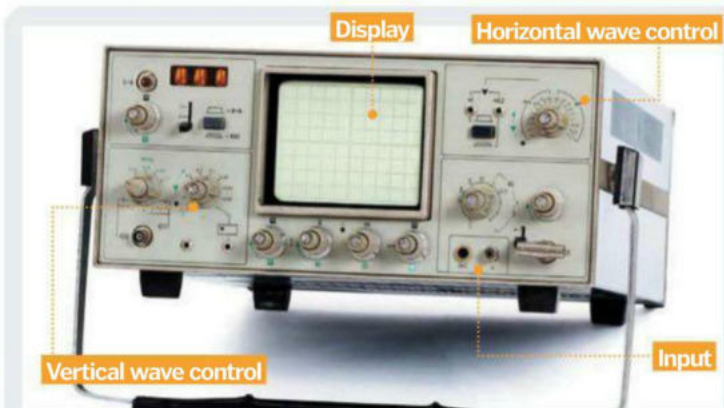
Why do these blood-sucking insects lose their appetite after a squirt of this spray?



Mosquitoes are attracted to humans and other warm-blooded vertebrates by sweat and the heat from our bodies. It's only the female of certain species of mosquito that will feast on our blood to feed her offspring and the only way you can stop her from doing that, thereby preventing an itchy bite and potential disease, is by making your skin a far less appealing prospect.

DEET is an acronym for a chemical compound that was developed by the US Army following World War II. Like many other insect repellents – both natural and synthetic – it essentially makes your skin a very nasty-smelling place for the mosquito to land and feed on.

It can be toxic in high concentrations, though as long as the DEET-based repellent is applied responsibly, it's both safe and very effective.



What are oscilloscopes?

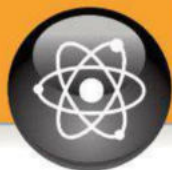
How these instruments track voltage



Oscilloscopes measure the shape of electric signals and display a moving graph called a trace that represents the voltage against time on a display. The varying electrical signal is picked up and sent to an electron gun. Here, a negative cathode ray is shot down a tube to the screen, accelerated by a positive anode, where the waveform is displayed. Waveforms can then be manipulated

on both the horizontal and vertical axes to accommodate different inputs.

In the case of medical oscilloscopes, electrodes attached to the skin pick up the regular electric variations in a heartbeat on a special oscilloscope called an ECG (electrocardiograph). One healthy heart should have the same rhythm as the next, producing a similar waveform, so, by analysing the output, doctors can quickly get an indication of potential problems.



HOW IT
WORKS
SCIENCE

How gallstones form

"The 'stones' range in scale from tiny granular crystals to the size of a golf ball"

Gallstones

What are these mineral deposits usually found in the gallbladder?

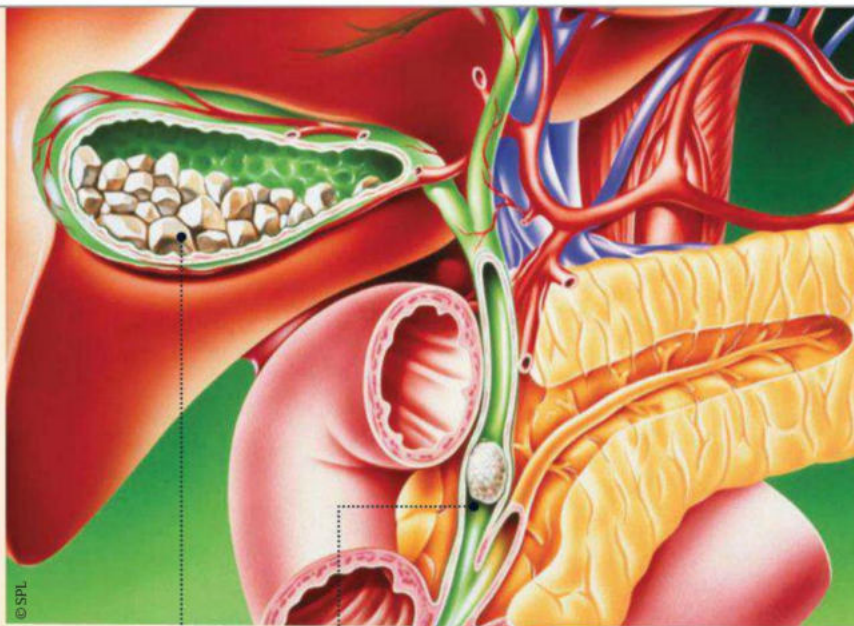


The gallbladder is a small, pear-shaped organ in which bile produced by the liver is stored. Over time the stored bile (composed of water, cholesterol, fats and natural salty detergents) becomes increasingly concentrated in order to better break down and absorb fats during digestion.

Gallstones, or cholelithiasis, are the tiny deposits of salts and cholesterol that can form if there's a chemical imbalance in the gallbladder, often due to an excess of cholesterol in the bile.

The 'stones' range in scale from tiny granular crystals to the size of a golf ball. Though they're usually formed in the gallbladder – and small stones cause no symptoms or pain whatsoever – if a large gallstone becomes stuck in one of the many bile ducts that connect the gallbladder and the duodenum (start of the small intestine) a patient can experience great discomfort. If a gallstone blocks the flow of digestive enzymes produced in the pancreas, a condition called pancreatitis can develop, which can cause acute pain.

Ultrasound scans are able to detect gallstones and, if necessary, the entire gallbladder can be removed using keyhole surgery. This generally low-risk procedure is called a laparoscopic cholecystectomy. Shockwave treatment can also be used to shatter the stones in situ, after which they can be passed naturally.



Gallstones
If there's an imbalance of chemicals in the bile, deposits of salt and cholesterol can form.

Bile duct
Although usually harmless, if a gallstone happens to get stuck in a bile duct, it can lead to intense pain and conditions such as jaundice.

Duodenum
Small stones can easily pass through the bile duct into the duodenum, where bile is usually introduced to aid digestion in the small intestine.



Robert Winston



Alice Roberts



Brian Cox



Ruby Wax



Marcus Brigstocke

WHAT MAKES THE WORLD WORK?

THE  TIMES
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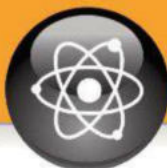
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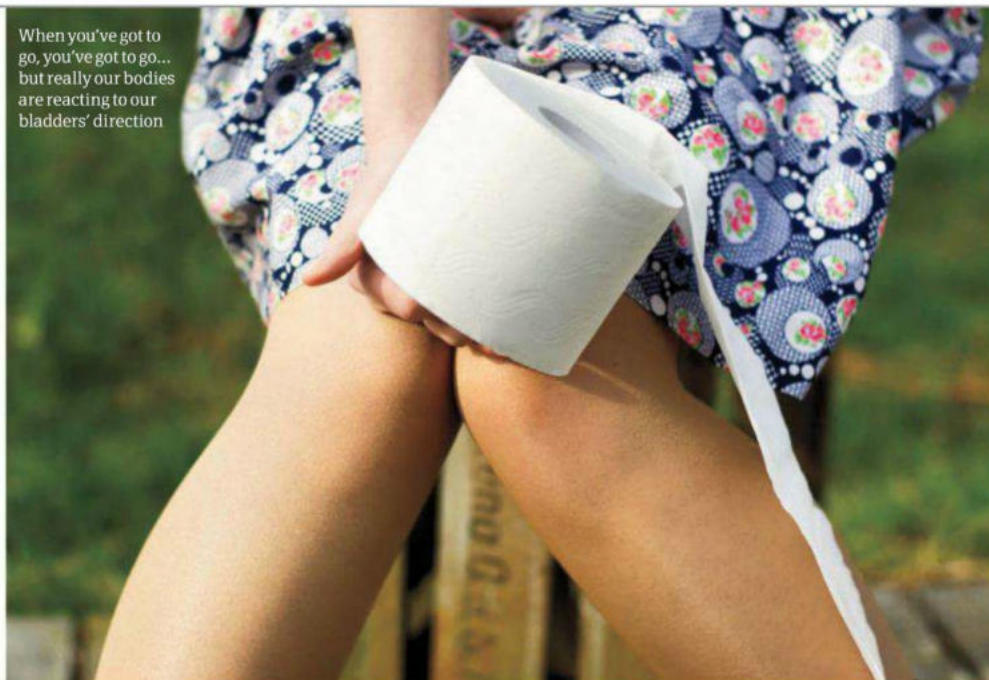


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"...the urinary system also helps to maintain the mineral and salt balance in your body"

When you've got to go, you've got to go... but really our bodies are reacting to our bladders' direction



THE COMPLETE URINARY SYSTEM

Kidneys

The kidneys turn unwanted substances in the blood into urine.

Ureters

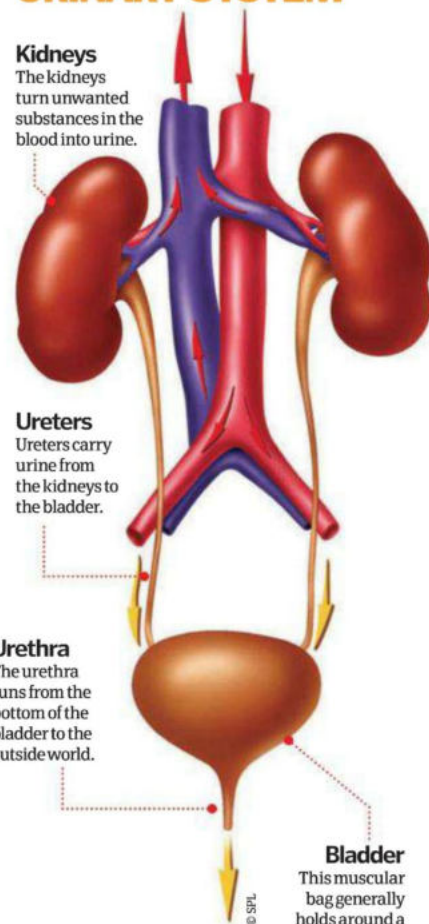
Ureters carry urine from the kidneys to the bladder.

Urethra

The urethra runs from the bottom of the bladder to the outside world.

Bladder

This muscular bag generally holds around a pint of urine.



How your bladder works

As a key part of the urinary system, the bladder is crucial to removing waste from your body



The bladder is one of the key organs in the urinary system and it stores urine following production by the kidneys until the body can release it.

Urine is a waste substance produced by the kidneys as they filter our blood of toxins and other unneeded elements. Up to 150 litres (40 gallons) of blood are filtered per day by your kidneys, but only around two litres (0.5 gallons) of waste actually pass down the ureters to the bladder.

Urine travels down the ureters and through the ureter valves, which attach each tube to the organ and prevent any liquid passing back. The bladder walls, controlled by the detrusor muscles, relax as urine enters and allow the organ to fill. When

the bladder becomes full, or nearly full, the nerves in the bladder communicate with the brain, which in turn induces an urge to urinate. This sensation will get stronger if you do not go – creating the 'bursting for a wee' feeling that you can occasionally experience. When ready to urinate, both the internal and external sphincters relax and the detrusor muscles in the bladder wall contract in order to generate pressure, forcing urine to pass down the urethra and exit the body.

As well as telling you when you need to pass fluid, the urinary system also helps to maintain the mineral and salt balance in your body. For instance, when salts and minerals are too highly concentrated, you feel thirsty to regain the balance. ☺

Incontinence explained

For the bladder to work correctly, several areas within it must all function properly. It is most commonly the failure of one of these features that leads to incontinence.

A common type of urinary incontinence is urge incontinence. This is when an individual feels a sudden compulsion to urinate and will release

urine without control. It is often caused by involuntary spasms by the detrusor muscles which can be a result of either nervous system problems or infections.

Another type is stress incontinence, caused when the external sphincter or pelvic floor muscles are damaged. This means urine can accidentally escape, especially if the pelvic floor is under

pressure (eg while coughing, laughing or sneezing). This kind of incontinence is most common in the elderly.

One modern remedy is a preventative implant that has been developed to replace post-event incontinence pads. This comes in the form of a collagen-based substance injected around the urethra in order to support it.



Urethras – all the same?

1 Women's urethras are much shorter than men's due to differing genitalia. Women are consequently far more likely to get bladder/urine infections because of this.

Getting the urge

2 The urge to urinate will normally come when the bladder reaches between 25 and 50 per cent of full volume to avoid reaching 100 per cent when involuntary urination will occur.

Duration

3 Urine can stay in the bladder for anywhere between one to eight hours before excretion. The time it remains there will vary depending on the amount of liquid consumed.

Can you drink urine?

4 Of course, this would not generally be recommended in normal circumstances, but yes, urine is completely sterile – it contains no bacteria, viruses or fungi.

How to keep healthy

5 It's advised to drink around 1-1.5 litres (2.1-3.1 pints) of water a day. This will keep the urinary system working most effectively. We lose more water than this but obtain some from food.

DID YOU KNOW? Everyone's bladder differs slightly in size. The average maximum capacity is between 600-800ml (1.3-1.7pt)

Inside the bladder

How this organ acts as the middleman between your kidneys and excretion

FULL BLADDER

Ureter valves

These sit at the end of the ureters and let urine pass into the bladder without letting it flow back.

Ureters
These tubes link the kidneys and the bladder, transporting the urine for disposal.

Bladder wall (detrusor muscles)

The detrusor muscles make up a layer of the bladder wall. These muscles cause the wall to relax and extend as urine enters, while nerves situated in the wall measure how full the bladder is and will signal to the brain when to urinate.

Internal urethral sphincter

The internal sphincter is controlled by the body. It stays closed to stop urine passing out of the body.

External urethral sphincter (distal sphincter)

This sphincter is controlled by the individual, and they control whether to open or close the valve.

Pelvic floor muscles

These hold the bladder in place, and sit around the urethra stopping unintended urination.

EMPTYING BLADDER

Internal urethral sphincter

This relaxes when the body is ready to expel the waste liquid.

External urethral sphincter (distal sphincter)

This also relaxes for the urine to exit the body.

Bladder wall (controlled by detrusor muscles)

These muscles contract to force the urine out of the bladder.

Urethra

Urine travels down this passageway to leave the body.

What is urine made up of?

A human bladder usually holds around 350 millilitres (0.7 pints) of urine, though male bladders can typically hold slightly more than those of females. Urine is made up of urea, the waste by-product the body forms while breaking down protein across the body. The kidneys will filter this out and pass it with extra water to the bladder for expulsion. Other waste products produced or consumed by the body that pass through the kidneys will also exit the body via this route. Typically, urine is made up of 95 per cent water and 5 per cent dissolved or suspended solids including urea, plus chloride, sodium and potassium ions.

URINE CONTENTS

Uric acid
0.6g

Bicarbonate ions
1.2g

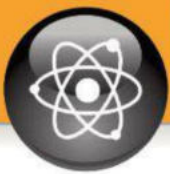
Creatinine
2.7g

Potassium ions
3.2g

Sodium ions
4.1g

Chloride ions
6.6g

Urea
25.5g



1. Like a whip

A collision from behind causes the head to jolt backwards before quickly being whipped forwards due to momentum.

2. Intervertebral discs

The shock-absorbing intervertebral discs allow for some vertebral motion – extension (back) and flexion (forwards); during whiplash, however, they are squeezed between the vertebrae. When the nerves are pinched between two vertebrae this can cause pain or numbness.

Anatomy of a collision

What happens to your body when your vehicle is hit from behind?

5. Further tearing

The ligaments are further damaged and often torn as they are stretched in the opposite direction.

HYPEREXTENSION

FLEXION

3. Torn ligaments

The cervical ligaments, tendons and muscles become damaged as the head is forced back into a position beyond its normal range of movement.

4. Jerk

When the head is jerked forwards flexion of the vertebrae takes place as momentum thrusts the head down onto the chest.

What is whiplash?

What is this painful injury caused when the neck is forced outside its normal range of motion?



Whiplash is a widespread term used to describe a number of injuries caused when the neck is suddenly and quickly forced to move back and then forth, or forward then back, or even from side to side. Such movement is often the result of a traffic collision, or following a blow to the head or fall during a contact sport.

The bones of the human spine serve to protect the fragile spinal cord which is located within. Of the 33 vertebrae of the human spine, whiplash affects the seven cervical vertebrae found at the top. Vertebrae are connected to one another by bands of fibrous connective tissue called ligaments. They are also connected to the surrounding muscles by tendons. In the event of an incident, damage can be done to both of these tissues in the vicinity of the neck.

During an incident where a vehicle has struck the victim from behind, the head will be forced very quickly back and then forwards, but likewise if the sudden neck movement is due to very abrupt deceleration, the head will instead be jerked in the other direction – ie first forward and then back. Both types can result in whiplash injuries ranging from neck stiffness and loss of movement to back and shoulder pain, headaches and even numbness that can radiate down the shoulders, arms and hands.

It should be noted that although whiplash is considered a fairly minor injury, any head or neck trauma should be checked out by a medical professional. However, most muscle and tissue injuries do not show up on X-rays, so sometimes it can be difficult to diagnose. 🌟

Tendons vs ligaments

While both tendons and ligaments are made of collagen cells, that's where the similarity ends. Ligaments are the tough connective tissues that link bone to bone by a joint and provide shock absorbency. They are strong and flexible bands of tissue but cannot be stretched. An overstretched ligament results in a sprain as experienced during whiplash.

Tendons, meanwhile, are the whitish fibrous cords that link one end of a muscle to a bone or other structure. Tendons look white as, unlike muscles, they don't contain many blood vessels.

A damaged ligament can often be surgically reattached to a joint bone, with mobility returning relatively quickly. A tendon, however, is part of the neuromuscular system and so electrical signals must be able to pass across the tendon to reach a muscle in order for it to react. Treatment typically involves a rest period, with a support, and then a gradual return to exercise.



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MILESTONES

MARKING MOMENTOUS MOMENTS IN SCIENCE

5 facts: Edward Jenner

1 APPRENTICE
Edward Jenner trained from the age of 14 for seven years in Chipping Sodbury, Gloucestershire, under surgeon Daniel Ludlow. In 1770, Jenner became apprenticed in St George's Hospital, Tooting, England.

2 CUCKOO
Jenner was elected Fellow of the Royal Society in 1788 following his publication of an in-depth study of the previously misunderstood life of the nested cuckoo. The report consisted of observations, experiments and dissections.

3 INSTITUTION
Off the back of his discovery and creation of the smallpox vaccine, Jenner became heavily involved with the Jennerian Institution in 1803, a society largely concerned with promoting vaccination and the eradication of smallpox.

4 KING
Due to his pioneering medical work, in 1821 Jenner was appointed physician extraordinary to King George IV, a great national honour. In the same year he was made mayor of Berkeley, his hometown.

5 STROKE
Edward Jenner died at the age of 73 from multiple strokes, the first leaving him paralysed and the second killing him. He was buried in the Jenner family vault at the Church of St Mary, Berkeley.

THE SMALLPOX VACCINATION

One of the most terrible diseases to have ever plagued humanity, smallpox claimed the lives of millions worldwide until it was eradicated in 1980



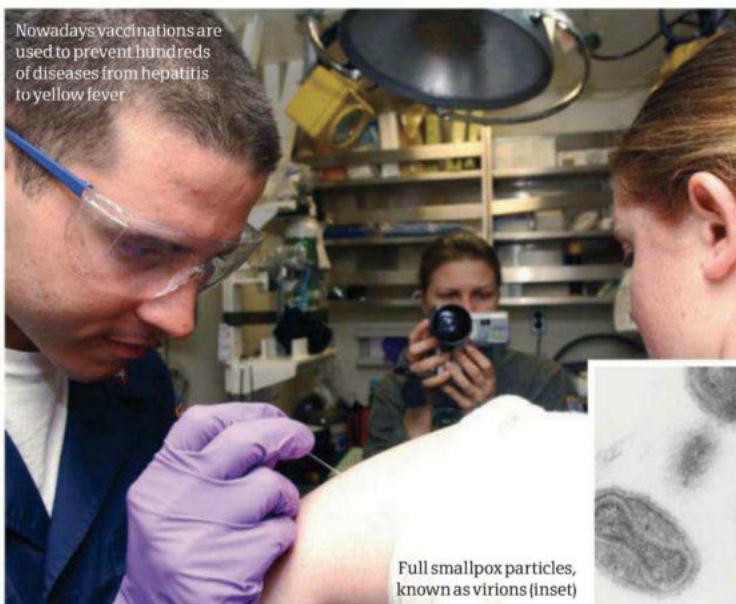
While our written records of the disastrous effects of the smallpox disease only extend back to the 15th century, there is compelling evidence that the disease emerged in human populations as far back as 10,000 years ago.

Indeed, upon close examination of the mummified remains of Ancient Egyptian Pharaoh Rameses V (who ruled c. 1150-1145 BCE), tell-tale pustular rashes can be seen, indicating that he most likely died from the disease. Since its emergence, both strains of the smallpox – variola major and variola minor – were left unchecked, leading up to an estimated 400,000 Europeans dying each year throughout the 18th century.

In 1796, however, the game changed. English physician Edward Jenner realised that individuals who caught the cowpox virus (an incredibly mild and non-deadly variant of the vaccinia virus) did not catch smallpox. Jenner then proceeded to test the theory in a series of cases that even included his own son, infecting each with the cowpox and then smallpox viruses. None of the test cases became infected with smallpox and, as a direct consequence, the first successful vaccine in the world was created.

Here, How It Works explores smallpox, its vaccine and the history of its effects, as well as its eventual eradication.

Nowadays vaccinations are used to prevent hundreds of diseases from hepatitis to yellow fever.



Full smallpox particles, known as virions (inset)

Smallpox symptoms

The incubation period for smallpox is roughly 12 days. After this, those infected experience fever, muscle pain, headaches, nausea and backache. These symptoms are then followed by the disease's characteristic pimpled rash across the sufferer's skin, which emerges first on the forehead and then proceeds down the body. Finally, the disease transforms into one of four varieties: ordinary, modified, malignant and haemorrhagic – each of which varies in its overall fatality rate.

JOURNEY TO IMMUNISATION

Developing inoculations has been a long, hard road, but the destination was worth it

68000-16000 BCE

The first smallpox virus evolves from a pre-existing rodent virus in Asia. One clade was the more deadly variola major strains, while the other clade included the less severe types of variola minor.

1500 BCE

The Ancient Egyptians bring smallpox over to Egypt from India and China. The virus proceeds to take hold, claiming many lives including, most probably, that of Pharaoh Rameses V.

700 CE

Arab armies carry the smallpox virus out of Africa and into Europe throughout the seventh and eighth centuries. The following Crusades continue this transference, leading to its widespread establishment in Europe.

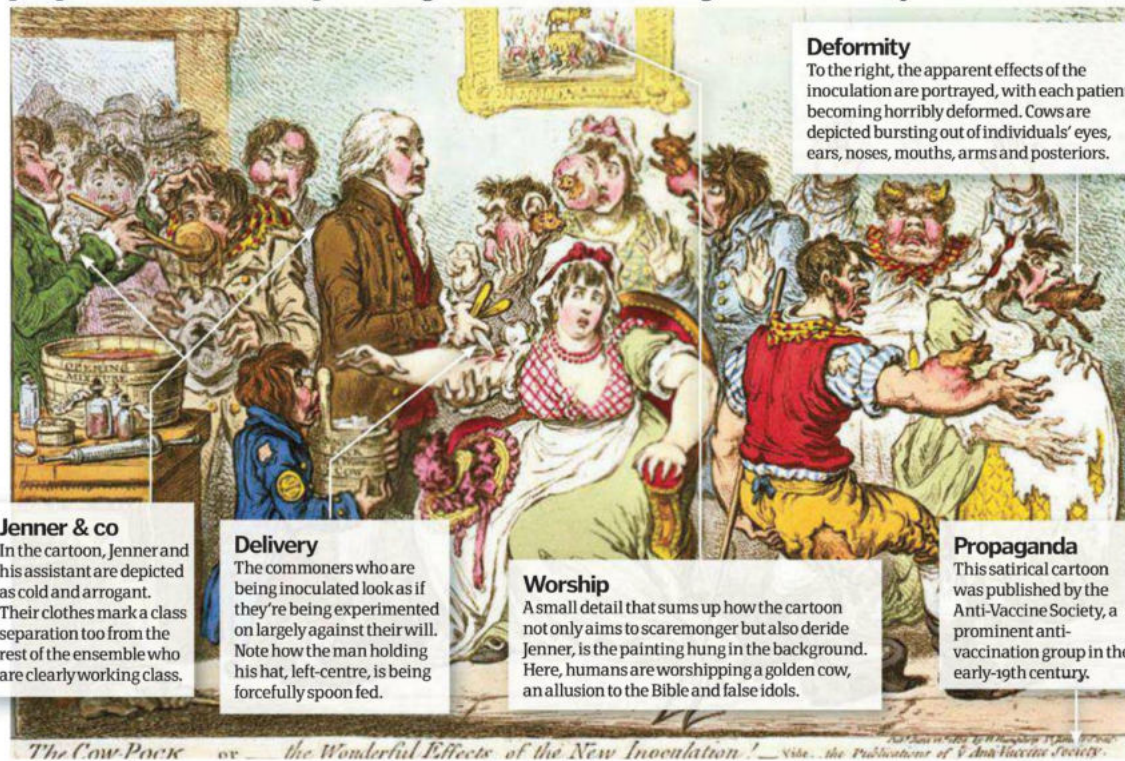
1585

Book XII of the 16th-century Florentine Codex – an ethnographic research project carried out in Mesoamerica – details how the native Nahuatl people of Mexico suffer greatly from smallpox (right).



The vaccination war

While Jenner's breakthrough is obvious from a modern perspective, the idea of injecting people with one virus to protect against another caused great controversy in his time



Jenner & co

In the cartoon, Jenner and his assistant are depicted as cold and arrogant. Their clothes mark a class separation too from the rest of the ensemble who are clearly working class.

Delivery

The commoners who are being inoculated look as if they're being experimented on largely against their will. Note how the man holding his hat, left-centre, is being forcefully spoon fed.

Worship

A small detail that sums up how the cartoon not only aims to scaremonger but also deride Jenner, is the painting hung in the background. Here, humans are worshipping a golden cow, an allusion to the Bible and false idols.

Propaganda

This satirical cartoon was published by the Anti-Vaccination Society, a prominent anti-vaccination group in the early-19th century.

Deformity

To the right, the apparent effects of the inoculation are portrayed, with each patient becoming horribly deformed. Cows are depicted bursting out of individuals' eyes, ears, noses, mouths, arms and posteriors.



Birthplace of the cure to smallpox

Edward Jenner's house, the place where he undertook the most important work in his formulation of the vaccination against smallpox, still stands today. Located in the town of Berkeley, Gloucestershire, the house is now the Edward Jenner Museum, which combines a traditional museum with an interactive learning environment for children and a historical archive. For more information, readers can visit www.jennermuseum.com.

The vaccine

The tools and techniques needed to fight smallpox

Virus

The smallpox vaccine is made from a virus called vaccinia, which is another pox-type virus that, while related to smallpox, can't cause it. It comes stored within a secure vial.

Antibodies

With the vaccinia now in the body, it induces antibodies that are cross-protective for all variola (smallpox) viruses, as well as many others including monkeypox and cowpox.

Blister

At the site of insertion, after four days a red, itchy bump develops, called the Jennerian vesicle. This blister fills with pus, then drains, dries and falls off eventually, leaving a scar.

Pricking

The vaccinia solution is inserted by a series of quick, shallow pricks into the surface of the skin (usually on the arm). This causes a sore spot and draws a little blood.

Needle

The smallpox vaccine is not delivered with a hypodermic syringe. Instead it is delivered using a bifurcated (two-pronged) instrument. The needle is designed this way so that it holds a droplet of solution each time.

1796

Edward Jenner realises that people infected with the non-fatal cowpox disease cannot catch any variant of smallpox. He proceeds to run a series of successful trials, creates the world's first vaccine and publishes his findings. He receives a very mixed reaction though.

1966

The Centers for Disease Control and Prevention (CDC) in Georgia, USA, launches a campaign promoting the importance of smallpox and measles vaccinations. A series of posters is created and distributed globally.

1975

The last known person to have been infected with the naturally occurring variola major smallpox strain is treated. Rahima Banu Begum (right) fully recovers and is still alive today with four children.



1980

Thanks to Edward Jenner, numerous other scientists and organisations such as the CDC, smallpox is eradicated totally in 1980. Today, small stocks of the virus are kept in a few highly secure laboratories.



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Welcome to... **TECHNOLOGY**

This month we tear apart an ultrabook to see how such a sleek laptop crams in so much power, before going on to look at the machines that can keep premature babies alive. Also discover how the bazooka deals an explosive punch, before heading back in time to see how far the humble watch has come.



32 Pressure washers



37 Capacitive gloves



38 Wristwatches

- 30** Light trails
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- 36** Incubators
- 37** Bazookas
- 37** Capacitive gloves
- 38** Evolution of... watches

 **LEARN MORE**



Light trails explained

How are these bright, abstract streaks of light caught on camera?



Light trails are a colourful and creative effect that photographers can capture by employing long-exposure shooting on their camera. The basic principle of light trail creation is that by manually dropping a camera's shutter speed to a very low level, light is captured by the sensor over an artificially long period of time, with every passing vehicle having its lights tracked and recorded over the visible distance of the road. This causes the lights to appear as a streaked moving line across the image, rather than a fixed point emanating from the cars' headlights.

To take a shot like this one, the following steps need to be taken. First, find a roadside vantage point in which no other moving objects are visible other than the passing vehicles. Second, mount the camera on a tripod, as stability is key while shooting long-exposure imagery. This is because if there is any camera shake while the unit's shutter is open, then the captured light will lose its direction and smudge across the entire image. Next select the shutter priority setting on the DSLR camera and drop the shutter speed to the desired level – for shots like these, this means at least a 30-second exposure. Finally, automatically focus on the scene's background and use an external remote to take the picture.

Interestingly, the very same process is also used in light painting, a technique where the streaked light is controlled by the photographer manually, using light-emitting diodes (LEDs) to draw custom streaks across a dark backdrop and thereby essentially 'painting' in light. ✨



AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Head to HIW Daily to see light painting in action
www.howitworksdaily.com



DID YOU KNOW? Artist Michael Wesely holds the record for longest exposure, capturing some shots over a period of three years

What is it?

This image shows a long-exposure photograph of a busy road at night. The photographer has achieved this by forcing the camera to use a slow shutter speed when shooting, which has allowed for stationary objects to be captured crisply, but blurs the lights of moving vehicles into colourful streaks.



The trails of light here are all the result of passing vehicles. They follow the direction that the vehicles were travelling while the camera was shooting



"As water cannot be squeezed, when pressure is applied it will naturally proceed to a zone of lower pressure"

How do pressure washers work?

Why does blasting grime with pressurised water get rid of the dirt that soap alone can't shift?



The basic mechanics of a pressure washer involve squeezing pressurised water through a series of small openings to create a powerful jet of liquid that's capable of dislodging dirt and grime from hard surfaces such as patios, walls and vehicles.

Domestic pressure washers are connected to the mains water supply by a hose attached to an intake valve on the outside of the washer. When the unit is switched on, the motor spins an angled swash plate at over 3,000 revolutions per minute. This swash plate is used to transform circular motion into reciprocating (up and down) motion to drive spring-loaded pistons up and down; it is these pistons that are responsible for drawing water into the contraption.

Every time the wide end of the angled swash plate passes, it pushes down on the top of the pistons, causing them to descend. Conversely, when the thin end of the plate passes, the pistons then rise back up to their original positions. The rising of the pistons draws water into the pump through a one-way valve. Because water cannot be squeezed, when pressure is applied it will always naturally proceed to a zone of lower pressure. Therefore when the piston falls and starts to press down on the water that's just entered the pump, the liquid must escape through another one-way valve – this time exiting into the outlet hose under a great deal of force.

The high-pressure water travels at speed along the outlet hose until it hits the closed trigger in the gun. Here the water is blocked – and the motor is temporarily interrupted. When the trigger is pulled by the operator, the motor starts up again, channelling a steady jet of high-pressure, high-speed water out through the tiny hole in the nozzle.

This model from Kärcher's wide range of domestic pressure washers features a reservoir for detergents, which have the added benefit of breaking down the dirt further. It also boasts a water-cooled motor, which helps it perform more efficiently.



Key elements of any power washer include pressure, heat, the cleaning solution and water flow rate

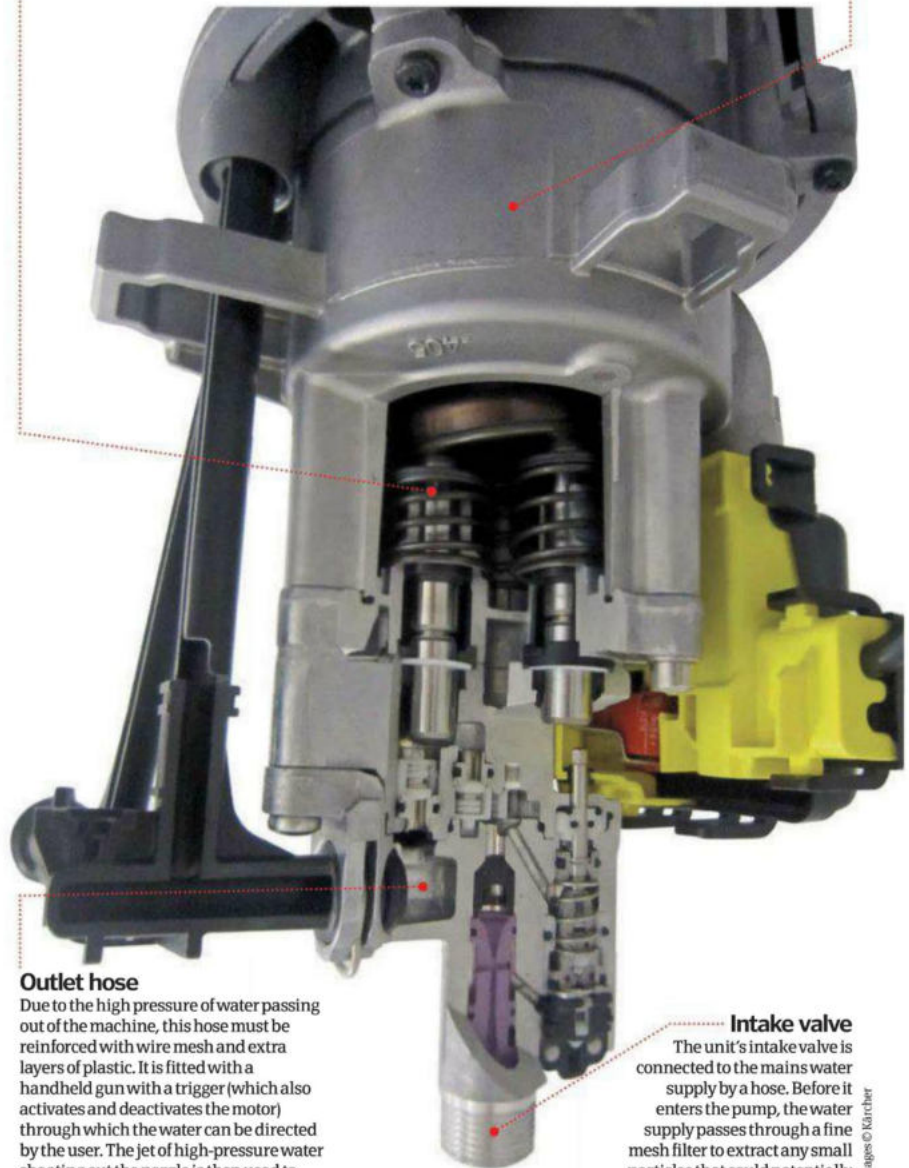
Inside the pressure washer's pump

Spring-loaded pistons

Powered by the motor, the pump is driven at high speed to draw water in. This one features a three-piston axial flow pump, which works like a suction pump that draws water in through one end and pushes it out of the pump towards the hose.

Electric motor

The pump inside the pressure washer is driven by a motor that is fed by the mains electricity supply. This model from Kärcher uses a water-cooled induction motor for extra efficiency.



Outlet hose

Due to the high pressure of water passing out of the machine, this hose must be reinforced with wire mesh and extra layers of plastic. It is fitted with a handheld gun with a trigger (which also activates and deactivates the motor) through which the water can be directed by the user. The jet of high-pressure water shooting out the nozzle is then used to tackle caked-on grime on hard surfaces.

Intake valve

The unit's intake valve is connected to the mains water supply by a hose. Before it enters the pump, the water supply passes through a fine mesh filter to extract any small particles that could potentially damage the pump.

Under pressure

As the name suggests, pressure is what drives these machines, but what is it? Pressure is the force applied to a solid, liquid or gas, which causes a substance's molecules to be squashed. The pump in a pressure washer increases the pressure on the liquid, causing the water molecules to bunch together. Unlike air, however, water cannot be compressed, so the crowding water molecules push against the walls of the container. If the fluid can move, when the pressure increases, the molecules have to move towards any point where the pressure is lower; in the case of the pressure washer that means through the outlet valve. Power washers can bump up the pressure of a typical garden hose by 15-50 times, or even more.

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"In the case of the Zenbook, ASUS had to create an entirely new fabrication and assembly process"

Inside ultrabooks

How is PC technology crammed into a super-slim, lightweight frame?

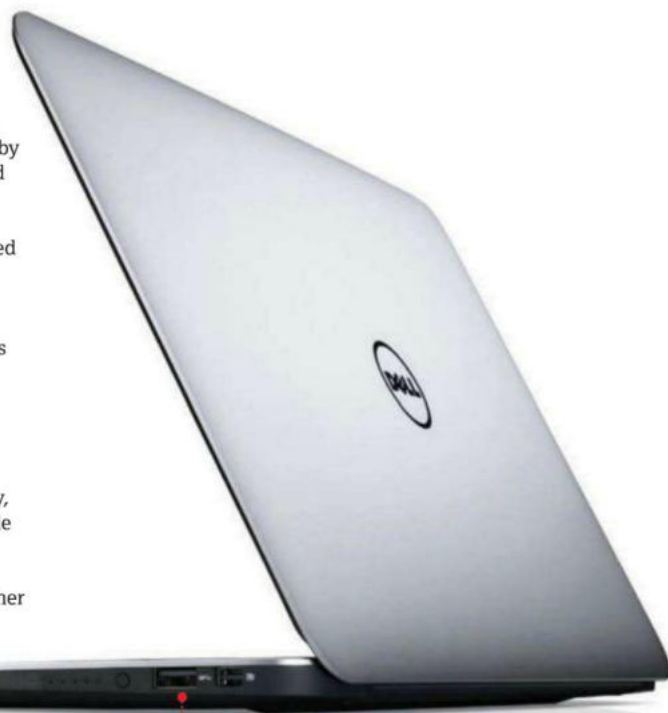


Intel originally coined the word 'ultrabook' for the long-overdue PC answer to the MacBook Air, the impossibly slim sub-notebook that Apple launched back in 2008. The idea was to design a notebook with comparable performance yet with a much greater battery life and further reduced weight and size. Several manufacturers came forward with ultrabook solutions, including Dell (XPS 13), Acer (Aspire S3), Toshiba (Satellite Z830) and ASUS – which recently launched its Core i5 processor-based Zenbook.

In the case of the Zenbook, ASUS had to create an entirely new fabrication and assembly process, as well as new machine tools in order to mass-produce its new ultrabook. But all ultrabook manufacturers first had to find new ways to minimise their current, smallest form factor portable to fit Intel's ultrabook definition.

Two major factors in a notebook's weight and size are the motherboard and battery: by improving general power consumption and redesigning the motherboard, the overall battery bulk has been trimmed and the motherboard components have been packed onto a drastically reduced printed circuit board (PCB) footprint.

The new generation of Intel processors – the Core i3, i5 and i7 central processing units (CPUs) – all have basic integrated graphics processing units (GPUs) that, while hardly capable of competing with the latest commercial graphics cards, are perfectly suited to the basic graphical number-crunching required of an ultrabook. Finally, the chassis has been designed using a single piece of lightweight aluminium, removing the need for an internal framework to hold components in place and thus, cutting further weight from the final build.



Modern materials

Aluminium, Corning Gorilla Glass and carbon fibre are all used to enhance both the look and performance of the Dell XPS 13.

Think thin

As well as packing power, a key quality of an ultrabook is its slimline chassis; the ASUS UX21E is only 3mm (0.12in) at its thinnest point.



The ultrabook project

The initiative for the ultrabook was started by Intel last year. The CPU giant offered significant financial subsidies to PC manufacturers willing to design an Intel-based solution to compete with the MacBook Air. The brief was to create a portable that fit the gap between a notebook and a tablet PC. According to Intel's executive vice president, Sean Maloney, ultrabooks have to be "thin, light and beautiful", less than 20 millimetres (0.8 inches) thick, use a Sandy Bridge Intel mobile processor and come in at less than \$1,000 (£630).

The current crop of ultrabooks, known as the Huron River phase, will be succeeded by the Chief River phase this June and finally the Shark Bay phase sometime next year. Each of these stages makes incremental enhancements to the basic specifications of an ultrabook and, significantly, adapts to match the new generations of Intel CPU microarchitecture.



Apple's MacBook Air was the original inspiration for the ultrabook revolution

According to Intel's definition, the Dell XPS 13 exceeds ultrabook pricing at £819 (\$1,100)

1. THINNEST



ASUS UX21E

The Zenbook might not be the cheapest of the three featured in this head-to-head, but it is the thinnest and most powerful.

2. CHEAPEST



Acer Aspire S3

Acer makes up for the lack of high-end features in its Aspire S3 ultrabook with a great-value price tag; the RRP is just £699.99 (\$799.99).

3. SEXIEST



Dell XPS 13

This Dell ultrabook makes a number of small compromises for an overall stunning design and it boasts the longest battery life of this trio.

DID YOU KNOW? Intel set aside \$300m in subsidies for manufacturers working on ultrabooks matching its specifications

ASUS Zenbook UX21E teardown

Take a look inside to see what makes this laptop so innovative

Chassis

The motherboard and all the ultrabook components fit directly into the unibody chassis which is made from aluminium.

Display

The UX21E features a super-bright yet energy-efficient screen.



Battery

A flatter and lighter removable battery has been compensated for by an energy-saving mode and a less demanding system.

CPU

Intel's current generation of Sandy Bridge i5 mobile processors has integrated graphics, removing the need for a separate GPU, streamlining hardware.

Motherboard

The motherboard has been significantly reduced compared to a standard notebook PC.

Disk drive

The 128GB solid-state drive is small, quiet and its static state saves more energy than standard hard disk drives.

Cooling

The Zenbook's slimline cooling system covers both the CPU and the motherboard chipset.

The statistics...

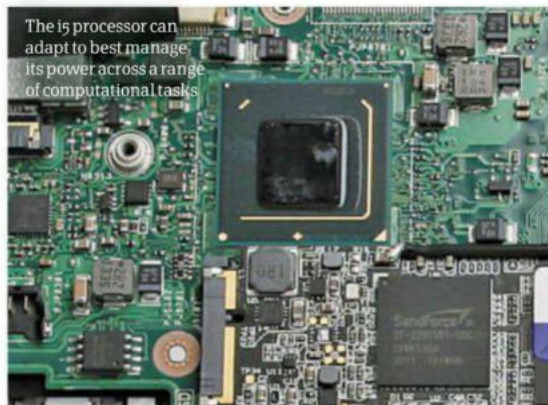
ASUS Zenbook UX21E

Length: 29.9cm (11.8in)
Width: 19.6cm (7.7in)
Depth: 0.3-0.9cm (0.12-0.35in)
Weight: 1.1kg (2.4lb)
OS: Windows 7
CPU: Up to Intel Core i7
Chipset: Intel Q567 Express Chipset
Memory: DDR3 1,333MHz SDRAM
Storage: Up to 256GB SSD
Battery: 35Whours
Display: 29.5cm (11.6in), 1,366 x 768px
Networking: Integrated 802.11 b/g/n; Built-in Bluetooth V4.0
Connections: 1 x USB 2.0, 1 x USB 3.0, 1 x headphone-out jack, 1 x miniVGA, 1 x microHDMI

What is Core i5?

At the heart of every ultrabook – or rather, its brain – is the Intel CPU. The core i5 2557M is an ultra-low voltage component designed with very thin and light laptops in mind. The Sandy Bridge series of this processor generation features an improved Turbo 2.0, which allows the CPU to idle at a relatively low 1.7GHz when the ultrabook is being used for mundane tasks such as word-processing and desktop applications. It can throttle up to a maximum 2.7GHz on a single core or utilise both cores at 2.4GHz depending on the task and the power-saving potential.

The CPU also has a small 32nm core and an integrated Intel HD Graphics 3000, both of which contribute to the ultrabook's overall energy efficiency and heat reduction. Essentially, the Intel processor is a fundamental factor in lowering the minimum size and weight threshold of each ultrabook.



The i5 processor can adapt to best manage its power across a range of computational tasks



"The primary task of a neonatal incubator is to maintain an even temperature within an enclosed unit"



Incubators are also called neonatal intensive care units (NICUs)

How do incubators work?

Why do some newborn infants need these protective chambers and what do they do?



Humans are homeothermic – in other words, we're capable of regulating our own body temperature within a certain range. So too are newborn babies but to a lesser extent. However, some infants –

usually those born prematurely – are only able to maintain their body temperature within a very small thermal window. They have poor heat insulation, a relatively large surface area and a small mass, making it very difficult for them to maintain their core body temperature. A small increase/decrease either side of the ideal can be catastrophic if left unchecked.

The primary task of a neonatal incubator is to maintain an even temperature within an enclosed unit that's designed to eliminate small eddies that can interfere with overall thermo-neutrality. This is achieved with a bespoke heater and fan, plus a container for water to add humidity to the air and avoid dehydrating the baby. At less than 31 weeks old, premature infants haven't undergone the keratinisation process necessary to protect their skin from drying out, making dehydration and heat loss through evaporation a real danger.

Modern, hi-tech incubators will include a servo-control that will regulate the incubator air temperature using a thermistor, a type of resistor whose resistance varies according to heat; this is attached to the baby's abdomen to monitor body heat. For severely premature neonates (newborns) oxygen may also need to be administered via a nasal cannula tube linked to a control valve within the incubator enclosure.

IV pole

A place to hang any necessary intravenous fluid bags that the infant may require.

Baby tray

This holds the newborn – usually on a mattress made of a less thermo-conductive material.

Digital display

Presents accurate readings of both infant and air temperatures and allows incubator heat levels to be set.

Heater

Usually servo-controlled to maintain a constant temperature throughout the unit.

Oval port

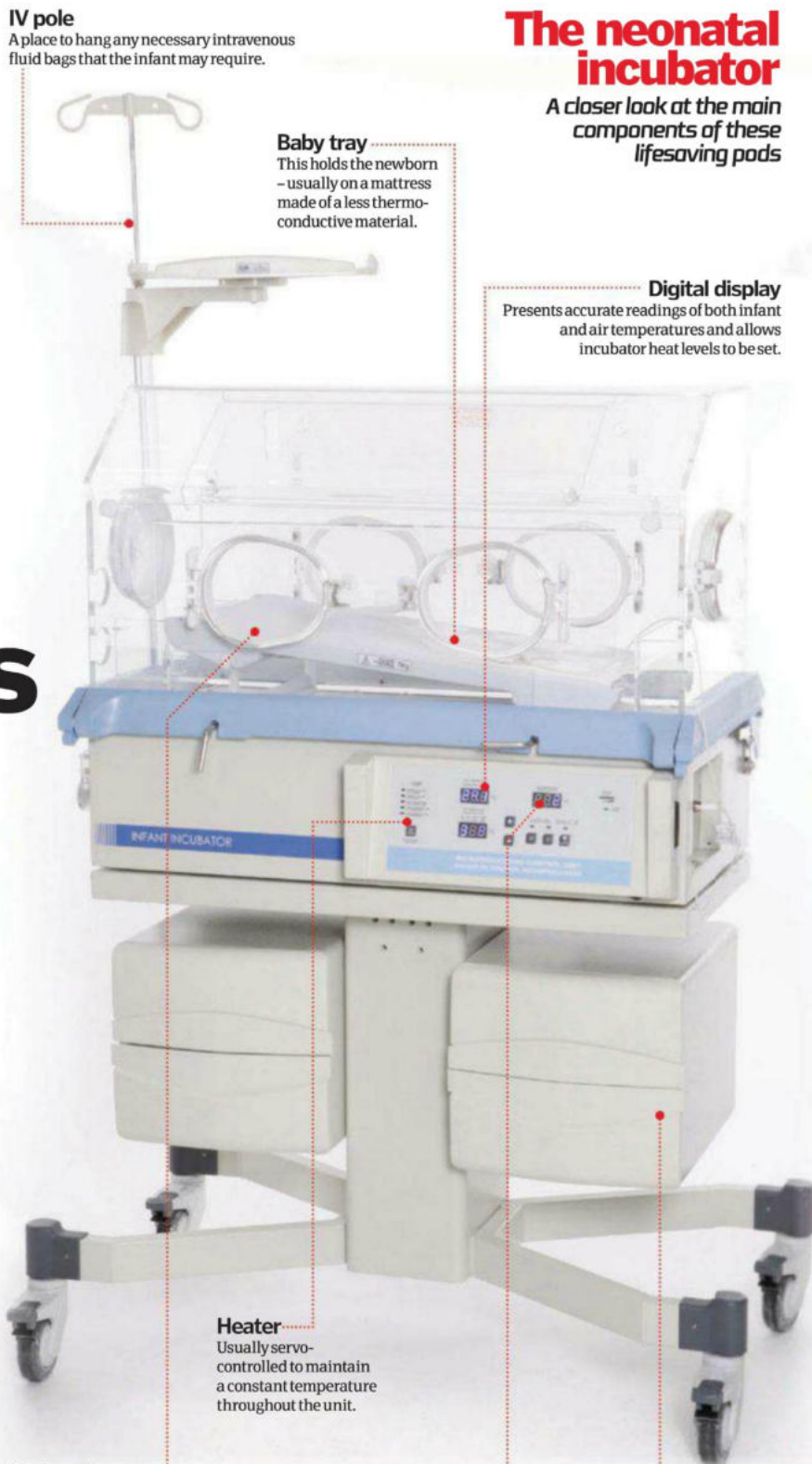
These points provide access to the infant and any equipment inside.

Hygrometer

Measures humidity within the enclosure and displays a precise reading.

Bowl

A receptacle to hold water, used to facilitate humidity in the pod.



The neonatal incubator

A closer look at the main components of these lifesaving pods

DID YOU KNOW? The Voltrex suit prevents current from flowing into the body allowing people to work with deadly voltages

Weave

A conductive material such as silver is used in the glove to allow the body's natural current to flow through.



Screen tech

The capacitive nature of today's touchscreen devices enables them to detect an influx of electrons, which is interpreted as a finger tap.

Bazookas explained

How personal grenade and rocket launchers work



During World War II there became a clear space on the battlefield for personal rocket-propelled grenade launchers, missile launchers and the like. Advances in tank armour and grenades whose blast radius exceeded the distance soldiers could throw them meant the bazooka was an invention waiting to happen.

And it did: fielded by the Americans in 1942, it was a basic beast consisting of a wired tube and pistol grip. The rocket was loaded and connected to the weapon's ignition wiring from the open rear end by one soldier, while another aimed and fired.

Modern 'bazookas' are specialised for use against personnel, tanks and even buildings. The British Army currently uses the light anti-structures missile (LASM) for urban warfare. The missile is loaded into a

telescopic, disposable launcher designed for single use. The rocket comprises a warhead, fuse and a propulsion unit and, when the trigger is pulled and the rocket fired, spring-loaded fins deploy to stabilise its flight while the force of its propulsion enables it to penetrate the target structure before its explosive payload is detonated.



The original M1 bazooka could penetrate armour up to 76mm (3in) thick

Capacitive touch gloves

What is capacitance and how can a pair of gloves transfer it?



Capacitance, in human biology, is your body's ability to store electric charge in the form of an electric field. Capacitive touchscreen technology takes advantage of this by taking a cue from the electrons that are allowed to flow from your fingertips via the microscopic salts, oils and moisture present in your skin, and interpreting that as a finger tap. Therefore, when you wear a pair of normal non-conductive gloves, the current is blocked and you can no longer interact with your device.

What the manufacturers of capacitive touch gloves do to overcome this problem is simply to use silver, or a similar capacitive thread, within the weave. This will have a high conductivity and low resistivity to your body's bioelectricity, allowing the natural electric current you generate to flow around the weave of the glove so you can interact with your capacitive devices as easily as you might without gloves.

The Panzerfaust 3

Advanced warheads

Advanced varieties include the PzF 3-IT, for tanks with reactive armour, and the Bunkerfaust, for bunkers, light armour and soft targets.

Sight

The sight mounted on the top of the Panzerfaust 3 is telescopic and can be reused.

Launcher

The main body is designed to be used once and discarded after launch, although the firing and sight units can be reused.



Standard warhead

The standard Panzerfaust 3 is equipped with a hollow charge warhead that can penetrate 700mm (28in) of armour.

Propulsion

The back of the launcher is filled with plastic granulate that gives the warhead an effective range of 20-400m (65-1,312ft).

Personal CNC for Home or Hobby

Don't Let Your Tools Hold Back Your Creativity

Tormach Personal CNC machines are the ultimate workshop tool. Whether you're a jeweler, artist, prototype builder, engineer, model maker or hobbyist, a Tormach PCNC will expand your possibilities and enable your ideas.

The PCNC 1100 Features:

- 3-Axis CNC Milling Machine cuts aluminum, steel, plastic, wood and more.
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Steel Clutch Plate (for Reproduction)
Cote 4.5 Steam Traction Engine
machined with the
PCNC 1100.



3-Axis Mill

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Shown here with optional
stand, LCD monitor, machine
arms, and accessories.





EVOLUTION OF...

CHARTING THE DEVELOPMENT OF
POPULAR PRODUCTS

Wristwatches

Nearly 600 years in the making, see how far the portable timepiece has come...



Watches popped up on the technology timeline in the 16th century, prompted by the invention of the mainspring. This simple piece of metal, coiled around an axle by the process of winding and allowed to uncoil at a regular rate, provided the kinetic drive.

The first portable timepieces were pocket watches which were worn on a chain; however, they only had an hour hand and they were terribly inaccurate, often losing several hours a day. Nevertheless, these were very much the commercial Rolaxes of their time, ornate items valued primarily as status symbols. They weren't very popular either, and it took another century before watches became a common sight.

The invention of the balance spring in the mid-17th century, which gave the mainspring a beat that was much more resistant to disturbances, brought with it the minute hand. Now watches were accurate to around a ten-minute margin for error a day and, with the realisation that watches could

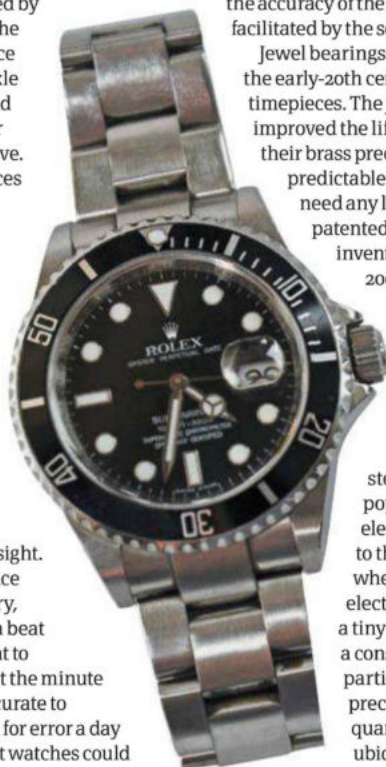
be used as scientific instruments, throughout the 17th and 18th centuries improvements to the accuracy of the balance spring were facilitated by the scientific community.

Jewel bearings were popularised in the early-20th century for accurate timepieces. The jewels themselves improved the life of the bearings over their brass predecessors, had a low, predictable friction and didn't need any lubrication. They were patented back in 1704, but the invention of synthetic jewels

200 years later, by

Auguste Verneuil, made jewel-bearing watches much more affordable, and so available to the masses.

The Fifties saw a steep rise in wristwatch popularity as the first electronic watches came to the fore, with a balance wheel controlled by an electromagnetic solenoid or a tiny tuning fork vibrating at a constant frequency. These particular models were the precursors to the modern quartz watch which is ubiquitous today.



Following the trends

Wristwatches weren't always a fashion statement like today

Up until the early-19th century, wristwatches were considered 'uncool'. In the Western world, pocket watches were a masculine status symbol and wristwatches – or 'wristlets' – were considered feminine and incapable of coping with day-to-day life.

That attitude began to change as soldiers discovered wristwatches were far more practical on the battlefield than a pocket watch, though this didn't come to a head until WWI. Millions of soldiers were given a wristwatch, something more accessible than a pocket watch while they were laden with kit. The war hero, returning home with his standard-issue 'trench watch' did much to dispel the image of the girly wristlet. Among the forerunners of the modern wristwatch at this time was Hans Wilsdorf, who strived to improve the design and accuracy of the device and whose company – Rolex – continues to win awards for its precision instruments today.

1511

Taschenuhr

The origin of the mainspring is uncertain, but German clockmaker Peter Henlein began making them around this time and is credited with popularising portable timepieces. His watch, the Taschenuhr, became a status symbol for the wealthy.

1657

Balancing act

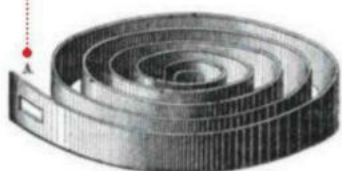
Again, the original inventor is in contention, but either Robert Hooke or Christiaan Huygens conceived the balance spring. This radically improved a watch's accuracy by regulating the oscillation of the balance wheel.

1675

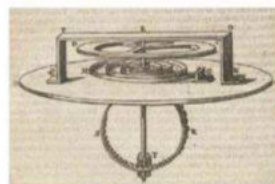
Royal endorsement

The pocket watch was popularised by Charles II. The fashionable king also introduced waistcoats and, as a result, a gentleman's watch evolved to the flat circular timepiece on a chain, to fit snugly inside the pocket.

> 1500s



> 1600s

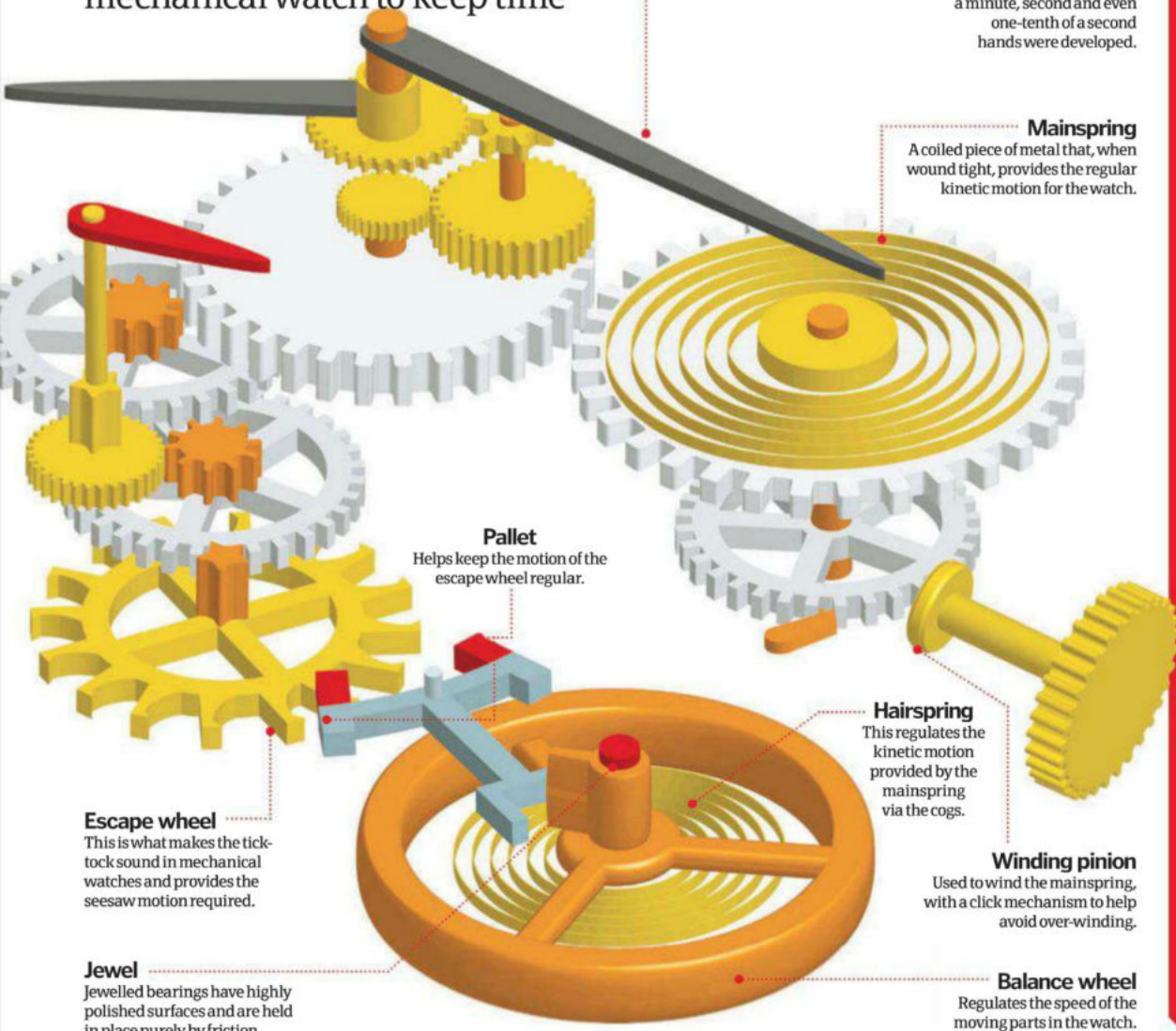


Wristwatch timeline

Take a look at how these time-telling tools have evolved over the centuries...

The mechanical wristwatch

The inner workings that enable a mechanical watch to keep time



Modern watches

How today's watches are ever advancing

While mechanical watches can still be bought today, they've largely been replaced by the quartz watch, which revolutionised the market in 1969.

The original design had a crystal that resonated at a regular 8,192 Hertz, a huge step up in accuracy from the analogue five Hertz that the mechanical balance wheel could achieve. It also removed all moving parts, putting an end to cleaning and improving shock resistance. The second generation of quartz watch technology seen in modern watches often uses low-power LCD displays and has an increased crystal frequency of 32,768 Hertz, with a discrepancy of five to ten seconds a month.

The only watches more accurate than this aren't self-sufficient: radio-controlled watches use a receiver to pick up radio time signals that regulate the time on a daily basis using the output from an atomic clock, which is accurate to within one second every 30 million years!

1750 Mass production

The start of the Industrial Revolution transformed watchmaking as it did many other industries. Batch-production of a watch's small parts on a large scale was made possible by factories and new machinery.

1902 Fake gems

Jewelled bearings were known to improve accuracy, but were very expensive. Synthetic sapphires and rubies made with aluminium oxide – using Auguste Verneuil's torch device – made jewelled watches affordable.

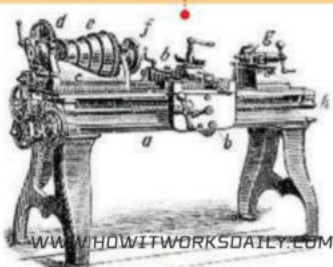
1969 Quartz revolution

The quartz watch marks the biggest revolution in wristwatch engineering since its inception. The Seiko 35 SQ Astron went on sale in 1969: curiously, Seiko didn't patent all of the parts, allowing all watchmakers to benefit.

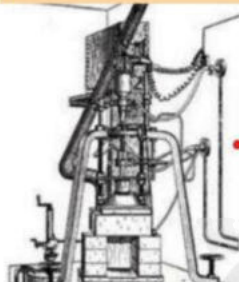
1983 Mechanical union

The quartz wristwatch really hit the Swiss mechanical watch industry. Nearly 14 years after the quartz digital was introduced, several struggling Swiss watchmakers formed Swatch. Today, it's the world's biggest watch company.

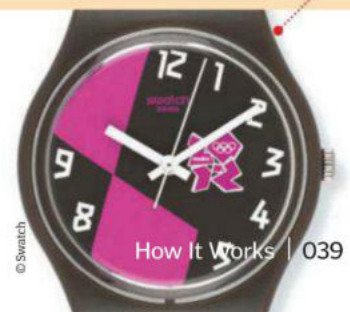
> 1700s



> 1800s



1900s>



How It Works | 039



Welcome to... SPACE

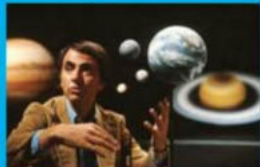
Let's face it, not many of us get the chance to venture into the cosmos so most of our knowledge has to come from films, the news and hearsay. Here we pick a selection of the most common myths about space and give you the cold hard facts; be warned, sci-fi movies may never be the same again!



45 Rocket boosters



46 Jupiter's auroras



48 Carl Sagan

40 10 space myths

45 Rocket booster recovery

46 Jupiter's auroras

46 Martian meteorites

47 The Carina Nebula

48 Heroes of... Carl Sagan

LEARN MORE



10 SPACE MYTHS BUSTED

How It Works sifts the cosmic facts from the cosmic fiction



What we know about space is analogous to the farthest reaches of the universe any manmade object has probed. In other words, it's an infinitesimally tiny drop of information in a vast ocean of potential knowledge that we'll only ever know – for certain – a tiny fraction of. Luckily, we can fill in all sorts of blanks

thanks to theoretical physics and join the dots between what we do know to come up with a likely conclusion. The problem with that is, as it's filtered down from the astrophysicists to those not so clued-in to the cutting-edge discoveries in astronomy, the truth – whether it's an established fact or a theory grounded in scientific evidence – tends to get

distorted. That and the fact that Hollywood has never let reality get in the way of a spectacular special effect has done nothing to dispel the galaxy of half-truths and outright fiction dressed up as truth that's been perpetuated ever since man first looked up at the sky. So here are ten of our favourite space myths that we'd like to shed some light on...

Sagittarius A*

1 The supermassive black hole at the centre of our galaxy is, for now, only scientific theory, but several celestial bodies in the centre are orbiting nothing – apparently – at thousands of miles per second.

The numbers game

2 Strictly speaking, there are currently 14 confirmed black holes, the closest being Cygnus X-1 which is around 8,000 light years from Earth.

Compression

3 Theoretically, anything can become a black hole as long as it is compressed to zero volume and yield infinite density (known as the Schwarzschild radius).

Dog eat dog

4 What happens when two black holes collide? Most believe that the one with the bigger gravitational force will suck up the other, creating an even bigger black hole.

In the middle

5 At the centre of a black hole reality becomes warped as matter is crushed to infinite density, so essentially space and time as we know them cease to exist.

DID YOU KNOW? Jim LeBlanc survived a space-like vacuum when a 1965 NASA test went wrong



I know I won't explode, but I'm still not getting out of this suit...

1 People explode in space

Space is a terrible, empty nothingness that's out to explode our fragile bodies. It's common knowledge that, when exposed to the vacuum of space, our blood will boil and our precious, pressurised internals will seek an exit from the nearest orifice.

THE REALITY

The vacuum of space is deadly, there's no doubt about that. But, actually, your connective tissues do an excellent job of holding everything in place and, thanks to your skin, neither will your blood boil; think about it – if that were the case then no one would be able to climb Everest or sky-dive and survive. You won't immediately freeze either because although the coldest parts of space are just above absolute zero (-273 degrees Celsius/-460 degrees Fahrenheit), there's little matter to transfer your body heat away. So the most immediate problem you will have is breathing: holding your breath prior to entering a vacuum can injure your lungs and, without oxygen, you will quickly black out. Exposure to intense UV radiation will cause serious sunburn too and without sufficient insulation, you will eventually succumb to the cold. Still, it's nice to know that if someone does accidentally eject you from the airlock, you won't pop like a balloon.



4 The Sun is yellow

You have eyes: look up into the daytime sky – though don't look directly at the Sun because it will damage your retinas. You can see it's yellow. Not only that, you know the star at the heart of our solar system is classified a yellow dwarf, so it must be yellow, mustn't it?

THE REALITY

By that same logic then, space must be blue... at least, during the day, until it burnishes an angry red in the evening and then turns black. But it's not and the Sun's natural colour isn't yellow either – it just appears that way because we're seeing it through the filter of the Earth's atmosphere, which absorbs some wavelengths of the Sun's rays. In fact, much like anything that burns at nearly 6,000 degrees Celsius (10,832 degrees Fahrenheit) at its surface, the Sun is white to the human eye and, if we were to look at it through the relative vacuum of space with no filter obscuring it, we'd see its true colour.

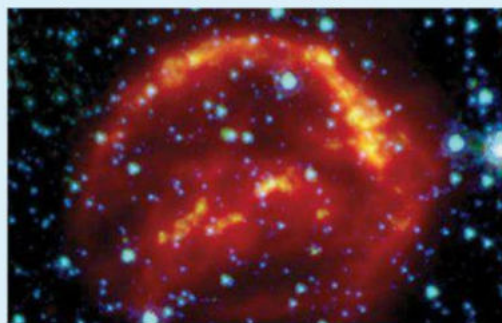
Of course the Sun's yellow... or is it?

2 SETI is part of NASA

The National Aeronautics and Space Administration (NASA) sends people to the moon in rockets, probes the solar system and beyond for its hidden mysteries and has SETI (the Search for Extraterrestrial Intelligence) as a subsidiary institution, constantly scanning the sky for signs of intelligent alien communication.

THE REALITY

While SETI has an agenda that seems to align with some of NASA's goals, they're two completely independent organisations. NASA was formed in 1958 as a response to Russia's launch of the world's first artificial satellite, Sputnik I. NASA is government funded and is typically allocated around one per cent of the annual US federal budget. The SETI Institute, on the other hand, was formed in 1984 and is dedicated to the search for and research of possible intelligent life in the universe. It's financed entirely by private contributions although some of these funds do come from NASA, as the two organisations have a history of collaborating on various projects.



If we have to point out the Great Wall in this photo, imagine what it's like from the moon!

3 The Great Wall is visible from orbit

It's a quiz-master's favourite: which is the only manmade object visible from orbit/space/the moon? To which we all know the answer: the Great Wall of China. That makes sense too, because it's huge, right?

THE REALITY

The dull reality is that whether the Great Wall of China is visible or not depends on the distance you're viewing from, the atmospheric conditions, whether you're viewing with the naked eye and, of course, if you're orbiting the right part of the world at the time! It's actually only visible with the naked eye in clear daylight, from a maximum low Earth orbit of around 2,000 kilometres (1,240 miles). And as the wall is crumbling in parts and is a similar colour to the land, it's quite hard to pick out. It's certainly not visible with the naked eye from the moon, as confirmed by Neil Armstrong, who could see continents and lakes during his 1969 lunar walk but no manmade structures.



"Quantum singularities are indeed powerful entities... but they still have to play by the rules of physics"

5 There is a dark side of the moon

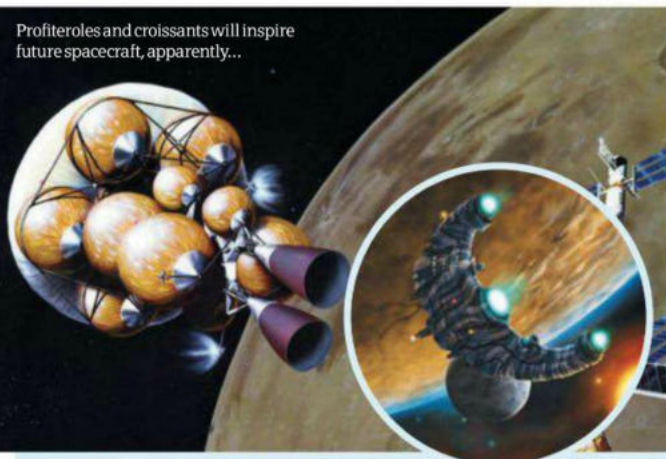
The moon rotates on its axis proportionally with the rotation of the Earth, so we only ever see one side of it and the far side is in perpetual darkness.

THE REALITY

In fact, that's mostly true. The moon does indeed spin in proportion with our planet so that we can only ever see exactly the same side of it from Earth. The Sun, however, lights up the bit we can't see as often as the near side of the moon. During a solar eclipse in particular, the far side gets completely illuminated while the near side to Earth is plunged into darkness. The inset image (right) is of a 68-kilometre (42-mile)-wide crater called Poinsot on the far side of the moon, clearly lit up by sunlight, taken by the MoonKAM system on the Ebb spacecraft on 15 March 2012. One of the reasons why the 'dark side' myth has been perpetuated may be Pink Floyd's famous album entitled *The Dark Side Of The Moon* released in 1973.



Profiteroles and croissants will inspire future spacecraft, apparently...



7 Space travel will mirror the movies

In the future, we'll walk in spaceships like on Earth, using artificial gravity. We'll view the vastness of space through shielded windows, point the bow to our next star system and brace ourselves for light speed.

THE REALITY

We're busting several space myths for the price of one here, though they're all straight out of television programmes like *Star Trek* and its science-fiction kin. For a start, there's no way of creating Earth-like gravity without something that has the mass of Earth. We can approximate it using centrifugal force, but gravity and mass are strictly proportional. For the same reason, travelling really fast in space will have no g-force effect beyond the rate of your spacecraft's acceleration. Windows are pointless; they're structurally weak compared with a solid bit of hull between you and the void, and it makes no difference what shape the ship is because, for you, up will always be the direction that the ship is thrusting in while it's accelerating. And what about light speed? Well, until we can figure out how to bend the rules governing Einstein's General Theory of Relativity, that will never be possible.

6 Black holes are inescapable

Black holes are the universe's Dysons, vacuuming up everything within an enormous radius and packing it into their mysterious epicentres with a force that even light cannot escape.

THE REALITY

Quantum singularities, the more scientific name by which black holes are known, are indeed powerful entities that help to shape the universe. But they still have to play by the rules of physics, which means that the farther you move away from the event horizon – the critical threshold at which light gets sucked into oblivion – the less force you need to escape the black hole's gravity. Which brings us to our second point: that although black holes appear to break the

rules, they can still be explained by physics. So a black hole with the same mass as our Sun will have the same gravitational force as our Sun, otherwise, by now, we may have succumbed to the awesome power of Sagittarius A*, the suspected supermassive black hole at the centre of the Milky Way.



Sagittarius A* isn't gradually sucking the Milky Way in, or it would have happened by now



The suspected smallest black hole is less than three times the mass of our Sun and resides in a binary star system (IGR J17091-3624) in the Milky Way.

DID YOU KNOW? Earth was 'seeded' with asteroids bearing life-supporting minerals over 3 billion years ago

8 Asteroid belts are deadly

Asteroid belts, like the one located between Mars and Jupiter, are a near-impenetrable obstacle course of fist-sized to kilometre-wide rocks hurtling chaotically at thousands of miles an hour – a potential minefield for anything traversing them.

THE REALITY

If any one of the probes that NASA has sent to Jupiter and beyond got hit by one of the rocks in the asteroid belt, it would certainly be damaged, if not destroyed. But the myth that's been perpetuated by the likes of *Star Wars* is that this area is jam-packed with asteroids, with scant few metres between them. In reality, though there are millions of hazardous rocks in the main asteroid belt, they have an unbelievable expanse to cross with around 1-3 million kilometres (621,000 to 1.86 million miles) between them. NASA estimated that the odds of a probe passing through the belt accidentally hitting an asteroid was one in a billion, meaning a space probe would have to be extremely unlucky for its trajectory to put it on a collision course.



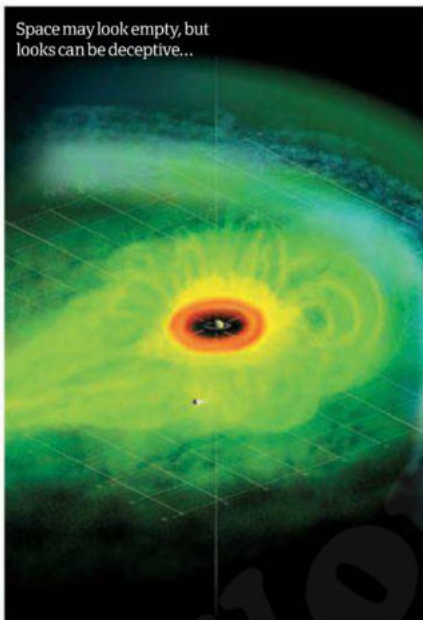
9 Auroras are only visible at the poles

Due to the way particles, excited by solar winds, are guided around Earth's magnetic field and focused at the poles, we only ever see auroras at our planet's north and south extremes.

THE REALITY

It's true that auroras are concentrated at the north and south end of a planet, but you won't always be looking north to see the aurora borealis and south to see the aurora australis. They're actually quite uncommon at the geomagnetic poles themselves where only unusual circumstances like a solar storm can cause the aurora to flare. Instead, they occur geographically at 60 and 70 degrees latitude where, in the north, they cut a west-east path across Canada through to Greenland, Scandinavia and Russia. In fact, from northern Alaska, under normal circumstances, you'll have to look south to see the aurora borealis.

Space may look empty, but looks can be deceptive...



10 Space is a vacuum

It's common knowledge that between the planets and gases there's nothing but dead pockets of empty space. No doubt this is at least partly the reason why we suffer explosive decompression when exposed to this 'vacuum of space' (also see space myth number 1).

THE REALITY

Actually, there is something in that space: plasma. Plasma is ionised gas, usually charged by heating or applying a strong magnetic field. It has some similar properties as gas, as with no distinct shape or volume it takes on the form of any container it's in. But unlike gas, it can form structures under the influence of a magnetic field. Because of this, it's considered the fourth state of matter – after solid, liquid and gas – and it actually makes up a massive 99 per cent of the known universe. There's not much of it on Earth, although you can see it in the flame of a candle, in fluorescent lighting and in those funky plasma lamps you can buy. In space though, the plasma is spread so thinly that, on the face of it, it appears to be a vacuum.

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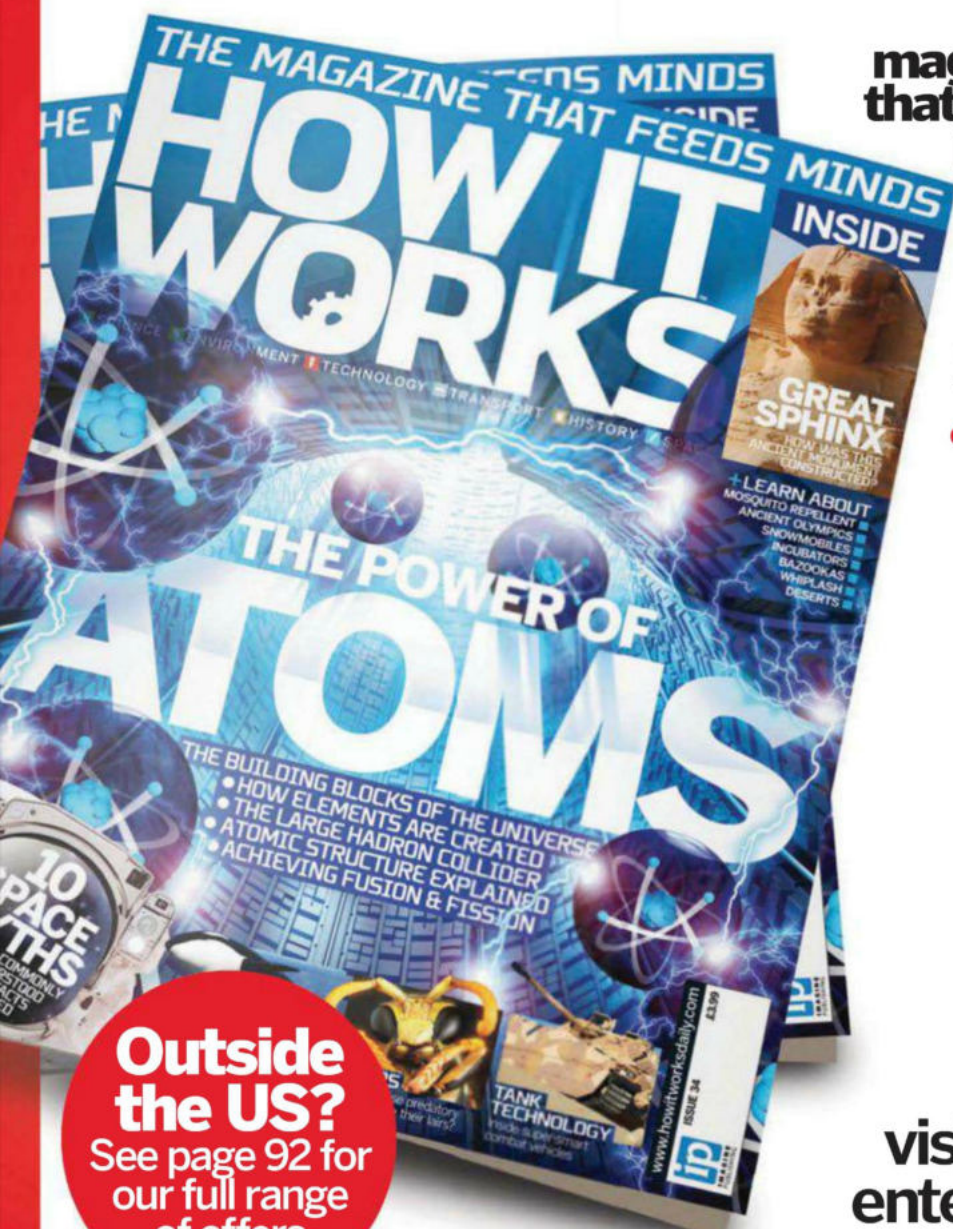
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Solid propellants

1 These are used for very large thrusts, eg to escape Earth's orbit. Solid propellant motors are very simple to design, though once ignited, they can't be shut off and so burn until exhausted.

Hybrid propellants

2 These are a combination of solid and liquid propellants, with a liquid oxidiser injected into a solid fuel. Hybrids are a lot cleaner than solid rockets.

Hydrazine

3 Commonly known as hypergolic rocket fuel, hydrazine simply needs nitric acid in order to ignite and is frequently used for propulsion when out in space.

Petroleum

4 Don't be fooled, you wouldn't fuel your car with this stuff! Rocket-grade petroleum is called RP-1 and consists of a highly refined kerosene mixed with liquid oxygen.

Alcohol

5 Early rockets, such as Germany's V-2 missile in WWII, used a mix of liquid oxygen and ethyl alcohol, although more efficient fuels were discovered soon after.

DID YOU KNOW? The ships are also used for other salvage operations as well as underwater cable-laying and nautical searches



The Liberty Star tows an expended booster from the Discovery space shuttle into port



Space ships

The Liberty Star and Freedom Star are designed by NASA specifically for the task of recovering boosters. They were built in a dry dock near Jacksonville, FL, in 1980 and 1981, are nearly 54 metres (180 feet) in length and displace over 1,000 tons of water. Twin engines provide 2,163 kilowatts (2,900 horsepower) to the propellers, but, curiously, also to two thrusters, one of which is a 317-kilowatt (425-horsepower) water jet thruster designed to protect manatees indigenous to the river where the ships are based. The vessels are crewed by ten mariners, nine SRB retrieval experts plus a supervisor, one NASA representative and several independent observers.

How to recover rocket boosters

Dropped from the edge of the atmosphere, here's how NASA salvages its solid rocket boosters

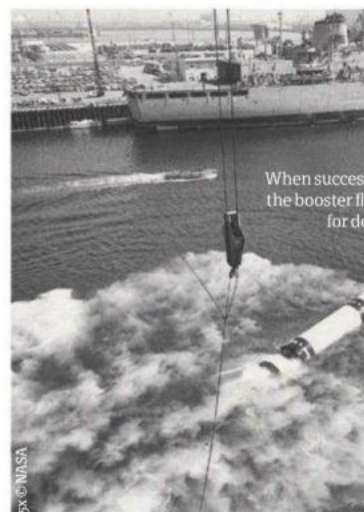


Solid rocket boosters (SRBs) are very expensive pieces of kit. In fact, they cost NASA around \$25 (£15.7) million to manufacture from scratch, so a cost-efficient recovery and refurbishment system was implemented in the Eighties that's still used today.

Most shuttle flights follow a predictable path across the Atlantic Ocean as they ascend into space. So, once the SRBs have expended 500,000 kilograms (1.1 million pounds) of solid rocket fuel, they separate from the rocket and begin their 72-kilometre (45-mile), parachute-assisted descent back down to Earth. Seven minutes after liftoff the SRBs will splash down into the ocean, around 260 kilometres (160 miles) from the launch pad and float helplessly in the water. That's when NASA's SRB recovery ships are deployed.

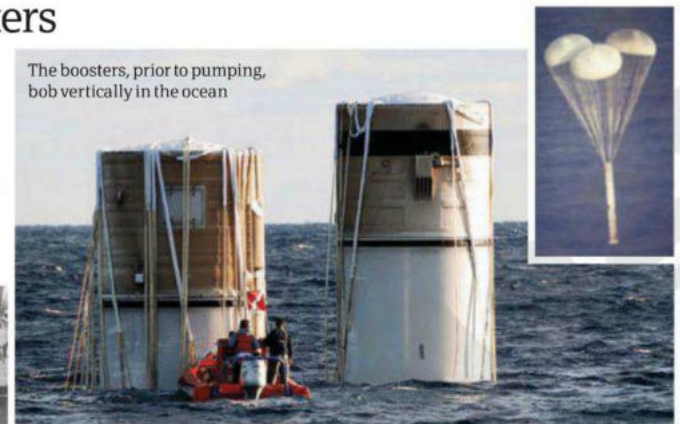
The Liberty Star and Freedom Star can recover one SRB each. Nearly everything can be salvaged from these boosters and both vessels have specialist tools for the job. The four parachutes are first detached and wound on to a reel, before the crew can focus on the SRB itself. Then a diver-operated plug (DOP) is deployed

and installed into the nozzle to help remove the water inside the booster. Air is then pumped from the ship, through the DOP and into the SRB, displacing the water. As more seawater is pushed out of the booster casing, it rises vertically until it topples onto its side, at which point it's ready to be towed back home to Cape Canaveral, FL, for dismantling.



When successfully pumped of water, the booster floats horizontally, ready for delivery and dismantling

The boosters, prior to pumping, bob vertically in the ocean



SRB refurbishing

Having been retrieved from the ocean and returned to NASA, the SRBs are dismantled and thoroughly inspected for damage before being refurbished for reuse on another shuttle flight.

Each SRB comprises a solid rocket motor, plus thrust vector control, structural, separation, recovery, electrical and instrumentation subsystems. The motor itself is loaded with solid propellant alongside its ignition hardware, which is mixed in three 2,730-litre (600-gallon) bowls and cast in special buildings, before being transported nearly 4,000 kilometres (2,500 miles) to its East Coast destination.



What are Martian meteorites?

How do these rocks from the Red Planet arrive on Earth?



Martian meteorites are chunks of rock churned up from the planet Mars, usually as a result of an asteroid impact, and expelled from its gravitational sphere of influence. As you can imagine, they're pretty rare on Earth; in fact, only 61 of the 41,000 meteorites that have ever been discovered on this planet have been definitively identified as having Martian origins.

The most recent confirmed meteorite from Mars to hit Earth has been named Tissint and it's also the largest to date, weighing 1.1 kilograms (2.5 pounds). It was found in the desert in southern Morocco last year and was classified as shergottite, a rock that came from somewhere within Mars's molten magma layer after an impact or expulsion by a volcano.

These meteorites are highly prized by scientists, who don't have any other practical way of analysing Martian rock samples. More importantly, Tissint can also provide clues as to the possibility of life on Mars; because it landed in a relatively lifeless area of Earth and was recovered quickly, any microfossils and Martian minerals altered by the presence of water will be relatively uncontaminated.



Ejection
Tons of Martian rock is thrown into the atmosphere by an asteroid impact and some of it escapes orbit.

Attraction
Earth's gravity pulls some of the Martian rocks, now travelling at thousands of miles an hour, into its atmosphere.

Impact
Of those Martian rocks that don't burn up in the atmosphere, a tiny percentage fall to the ground as meteorites.

What causes Jupiter's aurora

What scientists saw within the gas giant's northern lights

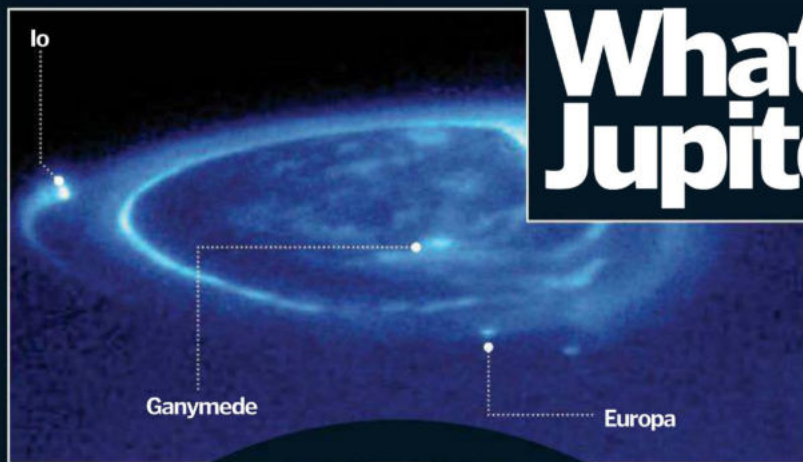


This is an image (top-left) of Jupiter's aurora, taken by NASA's Hubble Space Telescope in 1998. Auroras themselves aren't peculiar to Jupiter; they occur on Earth on both the North and South Poles and are called the aurora borealis and aurora australis, respectively.

Solar winds hitting the atmosphere and centring on the magnetic poles cause the phenomenon on Earth, but on Jupiter it's caused by the massive gas giant's own magnetic properties interacting with its upper atmosphere and exciting the gases that exist there, causing them to glow.

What makes this image particularly special is that you can also see the magnetic footprints of three of Jupiter's four largest moons within the Jovian auroral blue glow. Io, Ganymede and Europa's own auroras (which are labelled) show up as three blobs of light and the electric currents generated by these three satellites move along the magnetic field of Jupiter while bouncing in and out of the atmosphere.

This shot was taken from the ultraviolet part of the spectrum, so this particular perspective of the aurora cannot be observed with the naked eye. It shows the main oval centred on Jupiter's magnetic north pole.

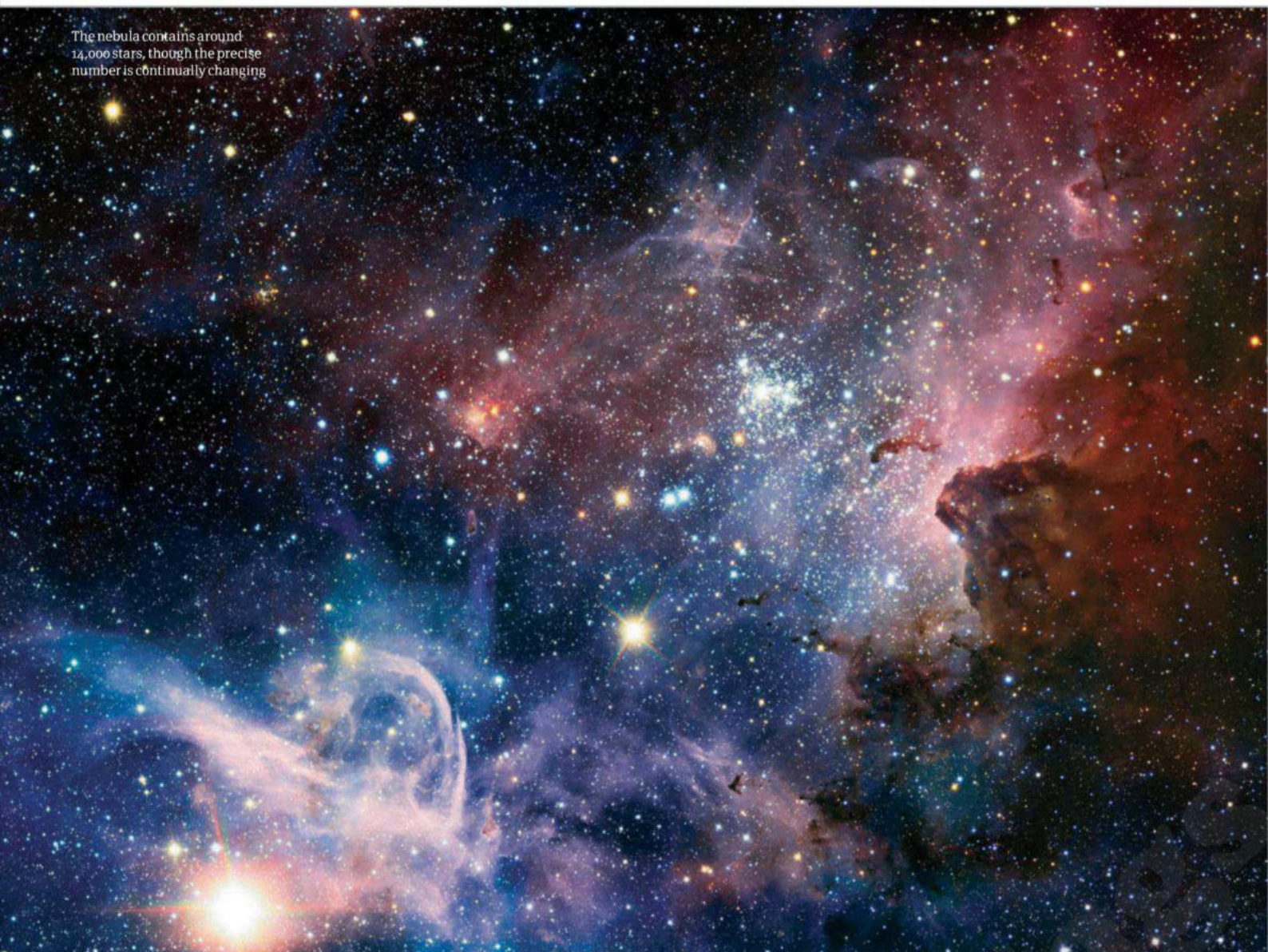


A more familiar shot of Jupiter, our solar system's largest planet

SN 2006gy, a star 150 times bigger than our Sun, exploded in 2006. It outshone its host galaxy, 240 million light years from Earth, for three months.

DID YOU KNOW? Eta Carinae was one of the brightest stars in the sky in the early-19th century but it has since greatly faded

The nebula contains around 14,000 stars, though the precise number is continually changing



The Carina Nebula

Look inside the galactic gas cloud and new star factory



The Carina Nebula is, astronomically speaking, close to the Earth at only 7,500 light years away. It was formed 3 million years ago and, far from being an inert cloud, it contains over 14,000 stars with this figure in constant flux. Evidence points to the fact that supernova explosions are on the up in the region and new stars are being born all the time. Stars are conceived when gravity gathers up molecules of the nebula gas, packing them tightly together and increasing the temperature. The cloud begins to rotate faster and the core reaches around 10,000

Kelvin (9,700 degrees Celsius/17,500 degrees Fahrenheit) at which point hydrogen molecules have broken down into their component atoms and fusion reactions start: the cloud has become a protostar – 30 times the size of the Sun.

The protostar collapses further until core pressure and temperature is great enough to sustain nuclear fusion. At this stage the star is contained in a dust envelope, a kind of exhaust from the process of the star's gestation, making the star invisible to the naked eye. In time, pressure exerted by radiation blows the envelope away to reveal the new star.

This recent image from the ESO's Very Large Telescope (VLT) has revealed the Carina Nebula in unprecedented detail. The bright yellow star near the middle is Trumpler 14, while the dark patches to the right are the dust envelopes disguising new stars. In the bottom-left is Eta Carinae; at around 100 solar masses, it's one of the biggest stars in the galaxy that radiates with 5 million times more power than our Sun. It's near the end of its life and is expected to go supernova in an astronomically short amount of time. In fact, some astronomers believe it could explode any time in the next millennium. ☼

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HEROES OF... SPACE

HISTORY'S MOST INFLUENTIAL SCIENTISTS



Carl Sagan

One of history's most well-known and respected astrophysicists, Carl Sagan worked closely with NASA for over 40 years and helped introduce space to the masses



Carl Sagan is remembered today not just for his outstanding achievements in the fields of astronomy and astrophysics, but also for his skill and enthusiasm for promoting science and interest in space, writing notable titles such as *Cosmos* and *Pale Blue Dot*, and presenting numerous television shows throughout the Eighties.

His work in astrophysics led him into many notable roles, including briefing Apollo astronauts before their flights to the moon, the designing of numerous robotic spacecraft – including the famous Viking Mars lander – and advising NASA on probable compositional and atmospheric conditions of distant planets and moons. Indeed, his work on Venus – where he accurately theorised its surface and atmospheric characteristics – made NASA's first visit to the planet possible, with Sagan working closely on the Mariner missions.

It was this ability to extend his view into deep space that made him so respected in the field of astrophysics, working almost continuously with NASA for over 40 years of his life. Being able to accurately predict the qualities of distant planets and moons was invaluable, allowing NASA and other space

Carl Sagan standing in front of the Viking lander, for which he was a principal researcher. The probe would later land successfully on Mars



institutions to better prepare for the realities of visiting them. Aside from his work on Venus, this was best demonstrated by his analysis of Saturn's moons (see 'The big idea' boxout) as well as his decoding of Mars's seasonal changes, in which he concluded that the planet's colour variations were not down to vegetation variation but in fact caused by massive windstorms.

Lecturing at Harvard and Cornell, working with NASA and advising on some of Earth's greatest-ever space missions however was just half of Sagan's story. Due to his outstanding knowledge of space and astrophysics, as well as his charismatic approach to both, he soon became a well-known figure on television, writing and presenting a number of TV shows that both helped inform and entertain the general public. *Cosmos*, a 13-part series in the Eighties – which today remains the most widely watched PBS series in history – saw Sagan cover a wide range of topics and was hailed for its special effects. Today, it is seen as the precursor to modern popular space television programmes such as Brian Cox's *Wonders Of The Universe*, covering everything from planets, asteroids and comets through to nebulas and the Big Bang.

1934

Carl Sagan is born in Brooklyn, New York.

1939

Sagan is inspired at the 1939 World's Fair which becomes a turning point in his life.



1941

He and his family experience a tough couple of years as relatives get caught up in WWII.



1951

Sagan graduates from Rahway High School in New Jersey.

1960

Sagan earns a PhD in Astronomy and Astrophysics.

1954

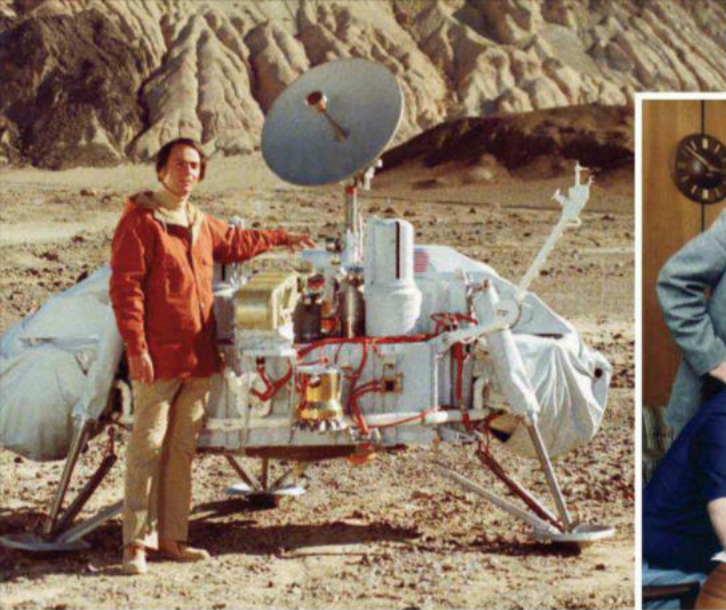
He attends the University of Chicago and graduates as a bachelor of Physics in 1955.



1968

Sagan lectures at Harvard University.

A life's work



Sagan and other members of the Planetary Society on its founding day in 1980. Today, the society has more than 100,000 members across 149 countries

FIVE THINGS TO KNOW ABOUT...

Carl Sagan

Cosmos

Sagan is best known for his popular science books and for his award-winning TV series *Cosmos: A Personal Voyage*.

Fair

When he was five his parents took him to the 1939 New York World's Fair. He later recounted that the experience became a turning point in his life, as he was blown away by the futuristic exhibits.

Billions

Sagan became associated with the catchphrase 'billions and billions', but he never said it. He used 'billions upon billions' once in his book *Cosmos*.

Asimov

Isaac Asimov, the Russian-American biochemistry expert considered the father of hard science fiction, famously described Sagan as only one of two people he ever met whose intellect surpassed his own.

Agnostic

While Sagan was not religious, he did not describe himself as an atheist, stating: "An atheist is someone who knows there is no god. By some definitions atheism is very stupid."

"Due to his outstanding knowledge of space and astrophysics, as well as his charismatic approach to both, Sagan soon became a well-known figure on television"

Sagan's foray into the public sphere continued with the publication of a number of books about space, including a tie-in *Cosmos* title and a much-celebrated sequel, *Pale Blue Dot: A Vision Of The Human Future In Space*. Sagan's prolific writing ability also saw him pen an introduction to Stephen Hawking's *A Brief History Of Time*, one of the most important books on astrophysics ever to be published.

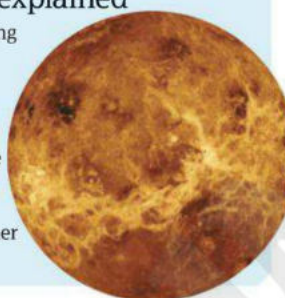
Towards the end of his life Sagan continued to help shed light on the uncharted depths of the cosmos and spoke frequently about it both on television and in numerous articles. Unfortunately, however, Sagan was diagnosed with myelodysplasia in the late-Eighties and,

after many years struggling with the disease, he died from pneumonia at the age of 62 in Seattle, WA, on 20 December 1996. Following his death, numerous awards were created in his honour and NASA, who he had worked so closely with, dedicated a new institution in his name – the Carl Sagan Center for the Study of Life in the Universe. Upon the centre opening in 2006, a spokesperson for NASA said:

"Carl was an incredible visionary, and now his legacy can be preserved and advanced by a 21st-century research and education laboratory committed to enhancing our understanding of life in the universe and furthering the cause of space exploration for all time."

THE BIG IDEA Sagan's most important thinking explained

Sagan's scientific achievements were many, however his thinking on the surfaces and atmospheres of distant planets and moons became one of his most notable. Sagan was the first person to accurately predict that Venus had an incredibly hot and dry surface, a conclusion reached by investigating radio emissions emitted from the planet. Further, Sagan also predicted that, due to its location, orbit and makeup, Saturn's moon Titan might possess oceans of liquid compounds, while Europa – another Saturn moon – could have a subsurface ocean of water. The former prediction was later confirmed by the Galileo spacecraft.



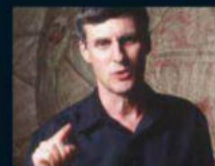
IN THEIR FOOTSTEPS

Those inspired by their work



Brian Cox

Popular scientist Brian Cox described Carl Sagan as his childhood hero and the person who first got him interested in space. Back in 2010, Cox told *How It Works*: "Without doubt the greatest science communicator in history was Carl Sagan. Not only because he brought the wonders of the universe into my life as an excited 12-year-old watching the *Cosmos* TV series, but also because [...] he passionately believed that science is the way to make the world a better place."



Steve Squyres

Steve Squyres was a student of Carl Sagan's and today is professor of Astronomy at Cornell University in Ithaca, New York. As with Sagan, his speciality is planetary sciences and, as such, he is principal investigator on the Mars Exploration Rover (MER) mission. Interestingly, Squyres has also won the Carl Sagan Memorial Award (in 2004) and the Carl Sagan Medal for Excellence in Public Communication in Planetary Science (in 2009).

1971

He becomes full professor at Cornell and directs its laboratory for planetary studies.



1972

Despite being an advisor to NASA since the Fifties, Sagan becomes more involved, working on the Voyager space probes.

1977

Sagan delivers the Royal Institution Christmas Lectures in London, England.



1980

He presents the TV show *Cosmos*, covering a wide range of scientific subjects.

1985

Sagan writes the bestselling sci-fi novel *Contact*. The book is adapted into a film in 1997.

1995

The sequel to *Cosmos* – *Pale Blue Dot* – becomes a *New York Times* bestseller.



1996

Sagan dies from pneumonia on 20 December in Seattle, Washington.



Welcome to... TRANSPORT

Leonardo da Vinci sketched his concept of an armoured vehicle way back in the late-15th century, but tanks have come a long way since then, as we demonstrate in our big feature in Transport this issue. Also explored is the kayak which can cope with many watery environments, plus how the snowmobile gets you from A to B in icy terrain.



54 Kayaks



57 Snowmobiles



58 Weapon stations

- 50 Next-gen tanks
- 54 Hydraulic truck cabs
- 54 Kayaks
- 57 Snowmobiles
- 58 Aircraft hardpoints

LEARN MORE



SUPER-SMART COMBAT TANKS

A new fleet of hi-tech and adaptable armoured vehicles is looking to revolutionise the modern battlefield



For decades tank design has been held in the vice-like grip of the 'Iron Triangle', a design mantra that states that any tank – in order to succeed on the battlefield – needs to be built on the sturdy columns of firepower, protection and mobility. The perfect tank, it was deemed, would be a seamless combination of these three key qualities – a machine that could withstand a host of armour-piercing shells, transport its crew both quickly and safely across a war-torn battlefield, and then deliver a series of explosive shells into enemy structures and vehicles.

Today's most advanced tanks are testament to the Iron Triangle – just look at the awesome firepower and armour

delivered by the M1 Abrams main battle tank – delivering, in varying degrees of success, heavily armed and armoured mobile fortresses capable of levelling city blocks and boosting an army's odds in any conflict they are deployed in.

However, times are changing. The modern 21st-century battlefield experienced today in 2012 differs radically from that experienced in the mid-20th century when much of today's top armour was conceived. The theatre of war in the present is more fluid, fast-moving and interconnected than ever before, demanding armies to react quickly and efficiently to any intelligence gathered to stay on top. In essence, intelligence and adaptability are now central to any armoured fighting vehicle,

and these qualities are rapidly reshaping the Iron Triangle into an 'Iron Pentagon' with which any new build must comply if it's to be an out-and-out success.

In this feature How It Works takes a close look at three of the most notable armoured fighting vehicles that are being constructed following the Iron Pentagon principle. These mighty machines not only offer bucketloads of armour and smart munitions, but also deliver advanced electronic architectures, near-omniscient sensors, super-fast internet networks, modular structures to adapt to any situation, plus revolutionary propulsion units.

So, strap yourself in and pay attention, as knowledge is power – and boy do these tanks go a long way to prove it! ☺



FRES

1 The MOD's Future Rapid Effect System (FRES) project awarded a Specialist Vehicle contract to General Dynamics for the ASCOD AFV in March 2010 – the first of the programme.

Global appeal

2 The CV90 is already in operation in Denmark, the Netherlands, Norway, Finland, Switzerland and Sweden. Its latest iteration is currently in evaluation in Canada, the US and Poland.

Hybrid

3 BAE-Northrop Grumman's new Ground Combat Vehicle uses a hybrid electric drive (HED) for propulsion, delivering a top speed of 70km/h (44mph) as well as enhanced efficiency.

Economy boost

4 By value, 80 per cent of the Scout SV vehicles will be completed in the UK, with 70 per cent of the supply chain companies UK-based, boosting the British defence industry.

Armadillo

5 The latest build standard for the CV90 is the Armadillo. This has been redesigned to focus on commonality between tank variants and is modular for easy configuration switching.

DID YOU KNOW? The Scout SV is currently set for trial introduction in January 2013

ASCOD SV: the scout

The Specialist Vehicle (SV) is the British Army's new, medium-weight armoured fighting vehicle built on General Dynamics' ASCOD platform. The platform is designed to fulfil a variety of roles that are currently each handled by one specialised but restricted vehicle. As such, upon introduction – the first trial vehicle is set to be delivered by January 2013 – the SV will be able to undertake all the diverse roles of these traditional vehicles, replacing them and reducing both costs and training timescales.

This is possible for two main reasons. The SV's modular architecture allows a number of specialised vehicles to be generated off the back of one common base platform (CBP). So, the SV can deliver some 17 variants, including the Scout reconnaissance variant, armoured personnel carrier, direct fire light tank, command and control vehicle, ambulance, through to recovery and repair engineering vehicles.

Another reason the SV is the 'Swiss Army knife' of the tank world is its integration of an advanced open electronic architecture system. This allows the SV's base vehicle to communicate with any systems unique to its specialised variants, enabling full sensor suite integration and easy control by its operator. It also helps manage the intelligence that can be captured, analysed and stored by the SV, which can be transferred over the latest Ethernet network to the rest of the battlegroup – be they on foot, in other vehicles or at base. This capability is a game-changer for the British Army.

The Scout is installed with an open electronic architecture to accommodate a full sensor array

Anatomy of the Scout SV

Find out which features make the Scout a revolutionary piece of technology

Surveillance

The Scout has been designed to provide near-omniscient surveillance, able to detect elusive targets in undergrowth, unmanned aerial vehicles and cloud-masked helicopters in all weather.

Turret

Despite its modest size, the Scout is installed with a spacious 1.7m (5.6ft)-diameter turret ring.

Track

Thanks to seven pairs of road wheels on each side, a wide track and a high power-to-weight ratio, the Scout SV's mobility beats most of its competitors.

Sensors

The Scout features an array of performance sensors coupled with the latest 20GB/s Ethernet intelligent open architecture, enabling it to capture, analyse and store over 6TB of tactical data.

Augmentations

Aside from providing a base unit for a variety of specialised vehicles, the SV can also be equipped with various extra features such as blast guards and far-target thermal sights.



"The SV's modular architecture allows a number of specialised vehicles to be generated off the back of one common base platform"

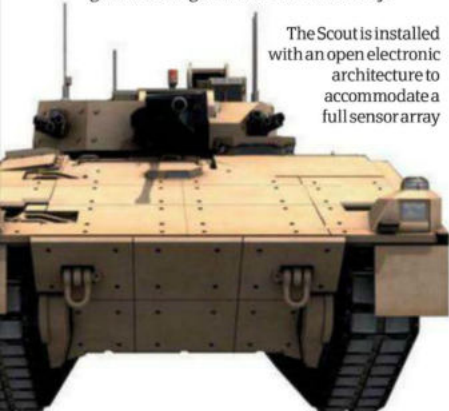
MODULAR MAYHEM

One of the SV's most impressive qualities is its modular design, allowing a stock base to be metamorphosed into many vehicle types

Thanks to its common base platform (CBP) and advanced electronic architecture, SV variants will be able to handle a host of roles. For example, the SV family offers a light tank, anti-aircraft and missile engine, repair and recovery

vehicle, command and communication vehicle and ambulance among other vehicles. Each of these can be outfitted to fulfil roles laid out in the British Ministry of Defence's Future Rapid Effect System (FRES) programme, a

project designed to create a large fleet of network-enabled, cross-spectrum armoured fighting vehicles. For example, the final phase of the development will also see a bridge layer and heavy-lifting vehicle developed.





"The GCV features an adaptive platform built around a space-efficient steel core hull"

CV90120: the tank killer

There is no escaping the CV90120's primary purpose: that of delivering a vehicle that offers the penetrative stopping power of a main battle tank, but with a weight, mobility and sensor suite comparable to a smaller and lighter specialist vehicle. And indeed it delivers, bringing the colossal Rheinmetall LLR/L47 120-millimetre (4.7-inch) anti-cannon to the battlefield, a gun that no armoured vehicle in the world can withstand if a clean shot is landed. What's more exciting, however, is its revolutionary new electronic architecture and systems, as well as its unique ADAPTIV cloaking device.

The ADAPTIV system (see the 'Real-life invisibility cloak' boxout below for an explanation of how it works) enables the tank to cloak itself over the infrared spectrum from any surveillance radars, accurately mimicking other less dangerous vehicles – therefore supplying misinformation to enemies. It can even vanish all together, with the system drastically reducing its signature at long and medium ranges. No other

system like this is currently on the market worldwide and, when you factor in that ADAPTIV is already being used in the field, then its game-changing qualities really shine through.

Another real high point of this next-generation fighter is its impressive suite of electronic survival features. These include laser, radar and missile approach warning systems, various multispectral, aerosol active countermeasures, a top-mounted attack radar that can identify precision anti-tank munitions, and a detailed vehicle information system (VIS). The latter supplies crew members with a vast array of battlefield information and intelligence, as well as various system parameters.



Armour

Unlike many older tanks, the CV90120 has been designed with a modular armour system, with the base structure receptive to add-on armour modules as well as the ADAPTIV cloaking system.

"A gun that no armoured vehicle in the world can withstand"

Anatomy of a CV90120

Find out the components that make this an invisible and deadly asset on the battlefield

Suspension

The tank's suspension and track system has been designed with a high ground clearance; this allows the CV90120 to effortlessly traverse snow and sand and adds extra protection against IEDs.

These clever hexagonal cells can not only distort a tank's signature but mask it altogether

THE REAL-LIFE INVISIBILITY CLOAK

The CV90120 is hardwired with BAE's ADAPTIV armour, a revolutionary new electrical camouflage system

The ADAPTIV system works by using lightweight, metallic, hexagonal pixels to cover a vehicle's armour, which themselves are powered by the unit's internal electrical system. The pixels are then individually heated and/or cooled using semi-conductors to either remove the tank's heat/radar signature entirely from surveillance radars – making it invisible to the enemy – or mimic the heat signature of another vehicle. As such, the CV90120 tank can quickly and quietly assume the appearance of a 4x4 and have its true threat remain undetected.

Interestingly, the ADAPTIV technology also allows the host vehicle to mimic the textures of other objects, minimising its radar signature even further and enabling it to appear like a range of inanimate natural objects, such as a large rock.

The CV90120's cockpit is installed with a defensive aid suite (DAS), a system that classifies targets and then gives threat warnings



DID YOU KNOW? The CV90120's ADAPTIV armour can mimic both natural objects and other vehicles

GCV: the mobile fortress

BAE Systems-Northrop Grumman's brand-new Ground Combat Vehicle (GCV) has been designed to provide the right mix of capabilities to adequately tackle the 21st-century battlefield, while also innovating in its delivery of cost-effectiveness over its scheduled 40-year life span. As such, the GCV has been designed to replace existing armoured personnel carriers and light tanks, while also providing a modular common chassis from which future specialist vehicles can be evolved.

The GCV features an adaptive platform built around a space-efficient steel core hull (the vehicle can carry a full squad of nine soldiers), an unmanned turret equipped with a 25-millimetre (one-inch) autocannon and coaxial machine gun, and a cutting-edge hybrid electric drive (HED) propulsion unit. This smart tank can also boast an integrated C4ISR electronic network, including embedded intelligence, surveillance and reconnaissance assets to connect personnel to varied information sources – a vital asset in modern warfare.

The propulsion unit is the real star of the show though, offering exceptional force protection and mobility in such a lightweight vehicle. The benefits are marked – read: a 20 per cent saving on fuel, 50 per cent fewer moving parts, 60 per cent reduction in total volume and increased on-board power delivery capabilities. Indeed, a standout feature is the ability to generate its own power even when stationary, a move intended to ready the GCV for the ongoing evolution of its systems.

The statistics...

GCV

Weight: 63,500kg (140,000lb)

Range: 300km (186mi)

Engine:
Hybrid electric drive (HED)

Power:
1,044kW (1,400hp)

Top speed: 70km/h (44mph)

Armament: 1 x 25mm (1in) autocannon; 1 x 7.6mm (0.3in) coaxial machine gun

Armament

The CV90120 comes with a colossal 120mm (4.7in) anti-tank gun – the Rheinmetall 120 LLR/L47 – which enables it to take down any contemporary armoured threat with consummate ease.

Modules

The latest iteration of the CV90 can be modified to become a personnel carrier, an ambulance, a command and control centre, recovery vehicle and mobile mortar-launching platform.

Electronics

Threat warnings are displayed via a vehicle information system (VIS) in the cockpit, an electronic architecture that also delivers speed corrections to reduce the probability of being hit.

The statistics...

CV90120

Weight: 35 tons

Range: 900km (559mi)

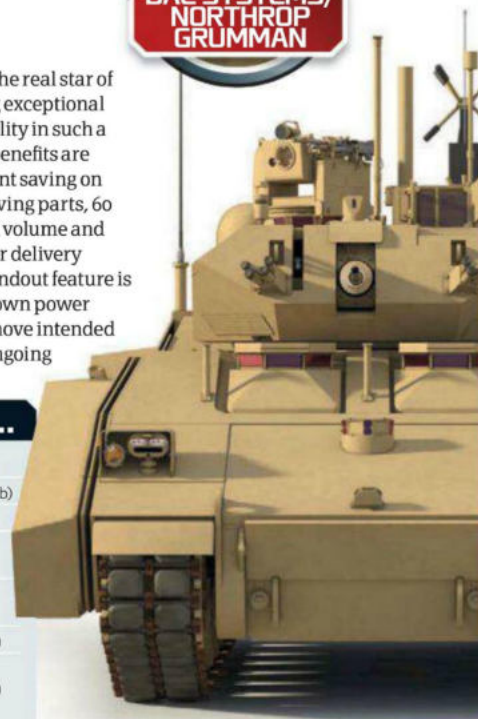
Engine: Scania V8 diesel

Power: 500kW (670hp)

Top speed: 70km/h (44mph)

Armament: 1 x 120mm (4.7in) smoothbore cannon; 1 x 7.6mm (0.3in) machine gun

Armour: 360-degree protection against 14.5mm (0.6in) armour-piercing rounds



The GCV's use of a hybrid electric engine means it will have a 30-40-year life span

Anatomy of a GCV

Discover a few reasons why the Ground Combat Vehicle is set to be widely adopted by armies worldwide

Armament

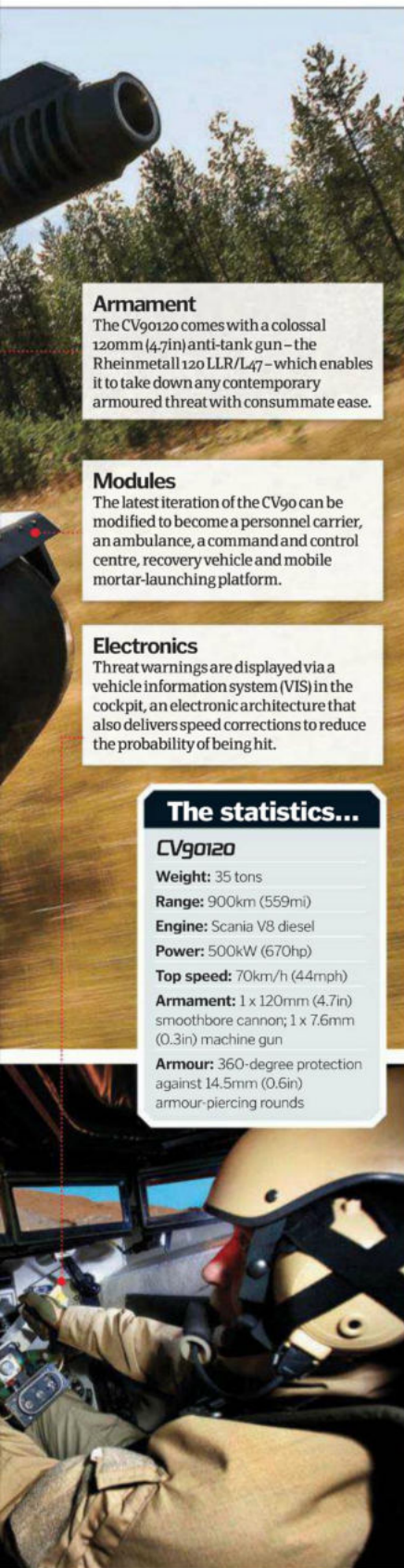
Despite its small size, the GCV is equipped with both a 25mm (1in) autocannon and 7.6mm (0.3in) coaxial machine gun, as well as an independent missile launcher operated by the vehicle's commander.

Propulsion

The GCV's hybrid electric drive engine delivers a 20 per cent reduction in fuel consumption over legacy vehicles, as well as a 50 per cent reduction in moving parts, essentially offering greater reliability.

Suspension

A lightweight and agile in-arm hydropneumatic suspension system consisting of seven road wheels and a 64cm (25in)-wide track delivers excellent mobility across difficult terrain.





"Today, the majority of kayaks are built from composite materials such as carbon-fibre and Kevlar"

Flat-nose truck cabs

How do these colossal cabs tilt to grant access to a truck's engine?



Flat-nose trucks, also known as cab-overs or COEs, are a popular design where the driver's cabin is positioned directly over the vehicle's engine, which itself is positioned over the front axle. The reason for this arrangement is that the truck will comply with strict maximum vehicle length restrictions imposed by many nations around the world. In addition, the shortened vehicle is easier to manoeuvre and turn when necessary, and is considerably more flexible when tackling winding roads.

Central to their design feasibility is the ability to position the driver's cabin over the engine, which itself is made possible by the integration of hydraulic lifting mechanisms in the rear-base of the cabin. These, once activated (which is only possible when the vehicle is stationary), lift the rear of the driver's cab upwards and away from the wheel base, revealing the engine and granting access to mechanics. For a more in-depth breakdown of a cab-over, see the 'Anatomy of a hydraulic truck cab' diagram.

Anatomy of a hydraulic truck cab



Cabin

The part of the cab where the driver steers the vehicle and sleeps at night.

Hydraulics

To the bottom-rear of the cab lies its hydraulic lifters, which – when activated – tilt the entire cab forwards, exposing its engine bay.

Electronics

Various sensors placed on the cargo hold/trailer are connected to the cab's electronic and control systems via rear-mounted ports.



Engine

Beneath the cab sits the truck's engine, which is commonly a four-stroke, turbocharged diesel setup.

Drivetrain

Extending backwards from the engine is the truck's drivetrain, which transfers the generated power to the rear wheels.

Kayaks explained

What makes these little boats so versatile?



Kayaks are small, narrow boats – most commonly single-seater – designed to transport their user over a variety of watery environments, be that calm, flat lakes, choppy coastal waters or torrential river rapids.

Due to their ability to traverse such varied terrains, kayaks can take many forms. For example, racing kayaks are long and narrow – often exceeding six metres (19 feet) in length – to reduce drag and maximise the distance per stroke generated by the paddler's oar. On the other hand, white-water kayakers are short and squat, often measuring in at no more than 1.5 metres (five feet) as stability and the ability to turn sharply are the key requirements when navigating jagged rocks and steep drops.

Indeed, when you consider this diverse usage, it won't come as a surprise to discover that there are over six main categories of kayak, including: recreational, oceanic, white-water, racing, surf and hybrid types.

Many of these categories are then further split into subcategories, as demonstrated in the white-water set. Here, both playboat and creekboat kayakers are available, the former offering a scooped bow and blunt stern to trade speed for stability – key for performing stunts and tricks, while the latter offers a higher float point and larger volume to mitigate against the threat of collisions when rapidly shooting down narrow gullies.

Today, the majority of kayakers are built from composite materials such as carbon-fibre and Kevlar, however older or speciality types are typically built from wood.



Rudder

Due to their great length, sprint kayakers can be fitted with a rudder to aid turning, which is controlled by the paddler's feet.

Chassis

Modern sprint kayakers are constructed from carbon fibre, fibreglass or wood. This ensures a light weight and therefore higher speed.

Beam

The beam, or widest part, of any flatwater kayak, such as the sprint variants, is rarely much wider than the width of the kayaker, greatly reducing drag.

5 TOP FACTS: KING TIGER/CROMWELL



Most feared

The King Tiger was the most powerful tank during World War II. It outgunned all other tanks creating fear in all who opposed it.

PzKpfw VI

The King Tiger was designated PzKpfw VI, which stood for "Panzerkampfwagen", German for "armoured battle car".

68 tonnes

A standard-outfitted King Tiger tank weighed in at approximately 68 tonnes, and its 700 hp, V12 Maybach engine enabled it to reach a top speed of around 23 mph.

40mph

The Cromwell's suspension could not handle 40 miles per hour over time even though the tank was capable of going 40 mph. Therefore the tanks were not to go over 32 mph.

Oliver Cromwell

The Cromwell tank was named after the English Civil War leader Oliver Cromwell.

How it worked

The gun of the King Tiger was the fearsome 88mm. Easily the match of any Allied tank gun, this helped to make the King Tiger a fearsome opponent.

The King Tiger also had five crew, however it had no dedicated front gunner, with the other man instead being used as a radio operator.

Equipped with a Rolls-Royce Meteor engine, derived from the famous Merlin aero engine, the Cromwell was capable of high speeds.

The Cromwell had 5 crew, a commander, a gunner a loader, a driver and a front gunner. Vital for fighting off enemy infantry attacks.



Scan this QR code with your smartphone to find out more!

Sloped armour. Inspired by the Russian T34 tank, the slope of the armour helped to deflect shots that could otherwise have crippled the tank or its crew.

The 75mm gun, while not as powerful as that fitted to the Tiger, was a useful support weapon for infantry.

Christie suspension. This suspension design not only allowed for ease of maintenance but also excellent mobility.

Suspension. The King Tiger featured a very complex suspension arrangement resulting in it being difficult and time consuming to produce.

Wide tracks, again a lesson learnt from the Russians. The wider the tracks the more the weight of the tank is spread, thus improving mobility over soft terrain.

KING TIGER/CROMWELL MkIV

Both the Cromwell and King Tiger tanks made their combat debuts in the Normandy campaign, however, both were very different types of tanks, the Cromwell being a manoeuvrable and fast medium cruiser tank, the King Tiger being a hugely complex heavy tank, weighing in at 68 tonnes. On the battlefield, while the King Tiger was a hugely capable machine, its complexity and sheer size often weighed against it and the Allies, using weight of numbers, air power and the fact the German tanks often broke down, were able to overcome the German armoured divisions and push them back, eventually liberating France.

KING TIGER

Crew: 5 **Height:** 3.09 meters **Width:** 3.76 meters

Engine: V12 Maybach HL 230 P30 (700hp)

Armament: 88mm KwK 43 (71 calibers), 1 hull MG 7.92mm coaxial MG 7.92mm, 1 commander's hatch MG 7.92mm

CROMWELL MkIV

Crew: 5 **Height:** 2.49 meters **Width:** 2.91 meters

Engine: Rolls-Royce Meteor, 600hp

Armament: 75mm Mk V ROQF gun, two 7.92 Besa machine guns

A50142 1:76 Scale King Tiger/Cromwell MkIV



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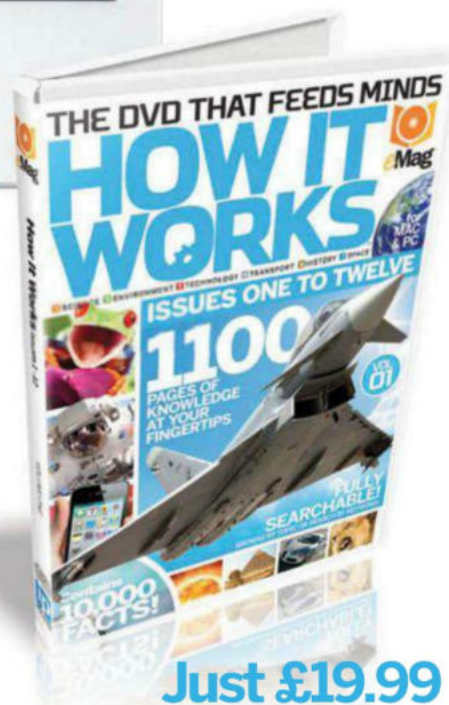
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DID YOU KNOW? The first patent for the snowmobile was submitted in 1927 by Carl Eliason for his 'motor toboggan'

Snowmobiles

How these vehicles traverse icy terrain



In the pursuit of getting from A to B as quickly as possible, it was only a matter of time before we told traditional skis to 'skid off' and invented the snowmobile. The roots for this snowy-terrain vehicle are in military technology, where the rubber in the off-road tracks was proven to work even in adverse winter conditions.

A Canadian inventor called Joseph-Armand Bombardier took the design, adapted and refined it to create the first single-passenger snowmobile in 1959: the Ski-Doo. Bombardier Industries has gone on to be a leader in the snowmobile market, while the snowmobile itself has become the de facto standard for fast travel across ice and snow-dominated landscapes.

Handlebars

Tanks and construction vehicles use variable track speeds to steer, while snowmobiles use the handlebars to turn the skis.

Chassis

A snowmobile chassis needs to be as strong and as light as possible: this model is just over 180kg (400lb).

Clutch

The engine uses a primary and secondary clutch system to ensure smooth gear changing at all times.

Snowmobile breakdown

The Polaris 800 Pro-RMK may be the latest in snowmobile solutions, but it's based on the same engineering innovations that the first commercial snowmobiles were designed with. A quartet of components – engine, clutch, tracks and skis – ensure this beast is capable of swift and reliable travel across snowy ground.

Skis

Wheels are near useless in snow, while skis spread the weight of the vehicle across a larger surface area.

Shock absorbers

This is one component that has dramatically improved through the decades. Shocks not only help you maintain control but also make the ride much more comfortable.

Tracks

The 38cm (15in)-wide tracks are similar to those on tanks, except made of rubber or aluminium. They can be equipped with studs too, for extra traction.

Engine

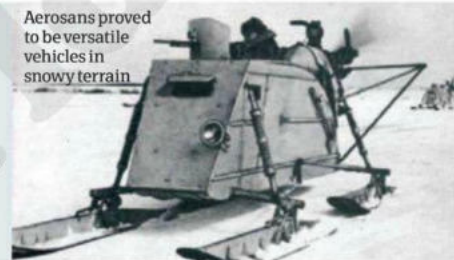
A similar design to engines found in jetskis, it has a large gear mechanism that turns the tracks.

The Coanda propulsion system was originally designed for jet aircraft

The aerosan

Military use of the snowmobile dates back to the early-20th century, when the Soviet Red Army used a light vehicle on skis that used an aeroplane propeller, called the aerosan. It was used as a transport and light-goods vehicle for medical supplies at first, but during the 1939-1940 Winter War against Finland, the KM-5 and OSGA-6 were equipped with a machine-gun and proved useful reconnaissance and raiding vehicles.

Aerosans proved to be versatile vehicles in snowy terrain





"There are three main types of hardpoint, each with its own unique advantages and disadvantages"



Hardpoints, also commonly referred to as weapon stations, are any part of an aircraft's airframe that has been designed specifically to carry an external load. These loads commonly involve additional weaponry, fuel or other forms of countermeasures, the latter usually consisting of braces of flares.

There are three main types of hardpoint, each with its own unique advantages and disadvantages. The first type is rail launchers, which are used to carry and launch large missiles and rockets. These comprise thin narrow rails mounted under an aircraft's fuselage, to which missiles are attached by a basic slot mount. These rail systems work by simply dropping the missile on command from the mount, with the weapon then propelling itself clear of the plane under the power of its own ignited engine and kinetic energy. Certain fighter aircraft sport modified variants of this rail hardpoint, often recessing it into the fuselage in order to reduce drag. In these cases, an ejector system is built in to the rail, which physically 'kicks' the missile out and away from the rail to ensure clearance.

Ejector racks make up the second type of hardpoint, although technically speaking the rack is not a hardpoint but is attached to one via a pylon. Ejector racks consist of braces of free-fall bombs and small rockets in a close-knit array hung beneath an aeroplane's wings. The positioning of the rack away from the wing surface ensures that control surfaces are not disrupted (damaging the handling and agility of the aircraft). The ejector racks also work by physically pushing the bomb/missile free, this time using explosive cartridges, which when engaged destroy the rack's weapon hooks. To make sure the primed weapon is definitely released, each rack is equipped with both primary and secondary charges, as a backup.

The third common weapon station is the wet hardpoint. These are referred to as 'wet' as they are plumbed and capable of interfacing with drop tanks mounted on them. This allows an aircraft to carry extra stores of fuel outside of its primary reservoir, greatly supplementing its maximum combat range. Importantly, despite their connection to the aircraft's fuel tank, wet hardpoints can still be jettisoned when empty to reduce weight and drag, and also be used to mount additional weaponry if needed.

Lastly, any aircraft's hardpoints are numbered from left to right. So, for example, if an aeroplane's left wingtip mount is number one, its right wingtip mount would be, say, number six, with all other mounts sitting in between numbered accordingly.

The A-10 Thunderbolt is prized for its ability to carry a wide variety of weapons on its numerous hardpoints



How does an aircraft carry weaponry?

Hardpoints enable fighter aircraft to carry a plethora of deadly weapons, gallons of extra fuel and electronic countermeasures

Rails

Rail launchers are commonly fitted under the fuselage of a fighter jet, dropping missiles free-fall prior to rocket ignition.





AMAZING VIDEO!

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See the AGM-158 JASSM cruise missile explode!

www.howitworksdaily.com



DID YOU KNOW? Certain aircraft, like the F-18, can recess some of their hardpoints to improve aerodynamic capabilities

Pylons

Ejector racks or single missiles can be mounted to an aircraft via underwing pylons, which provide clearance for additional, or larger, munitions.



An F-14 Tomcat has a maximum load of six AIM-54 Phoenix missiles



Swing

Fixed-wing aircraft can mount weapons under their wings and on their tips, something not possible with swing-wing aircraft.



Two F-16s carrying a host of air-to-air missiles, as well as external fuel pods on their hardpoints



Welcome to... ENVIRONMENT

Things are getting seriously hot in Environment this month as we explore our planet's most arid terrain and the flora and fauna that call the desert their home. To cool off, head out to the ocean to see how killer whales work as a team to catch their prey. Also learn how chicken eggs form – just don't ask us which came first!



64 Chicken eggs



67 Wasp nests



70 Killer whales

60 Deserts

64 Chicken eggs

67 Wasp nests

67 Condors

68 Grand Prismatic Spring

70 How killer whales hunt



LEARN MORE

HOW DESERTS WORK

What might at first glance appear to be a barren wasteland is actually teeming with life and unique terrain



Deserts cover one-fifth of the Earth's surface and are fascinating places. Take the Namib in southern Africa.

Considered the world's oldest desert, it may have been dry for 1 million years. The Namib reaches the sea along the barren Skeleton Coast, which is named after the shipwrecks that litter the dunes. South of the Skeleton Coast is the Sperrgebiet (which translates as 'prohibited area'), where public access is restricted to prevent diamond hunters combing the coastal dunes for gems.

The Namib is a hot desert with summer temperatures reaching 30-40 degrees Celsius (86-104 degrees Fahrenheit), but deserts can be cold too; for instance, the ice-covered continent of Antarctica is Earth's largest desert. A desert is simply a place where average rainfall is less than 0.5 metres (1.6 feet) per year. Indeed, some deserts remain rainless for months or even years.

Most of Earth's hot deserts lie within 30 degrees latitude of the equator. Examples include Africa's vast Sahara Desert.

Gigantic atmospheric currents force air to sink and warm at these latitudes, which in turn suppresses rainfall.

The Namib and Atacama are coastal deserts lying beside cold ocean currents – the Benguela and Peru Currents, respectively – that cause air above them to cool. Cold air can hold less water, reducing the rain falling on nearby warm land. These deserts are among Earth's

driest. Most moisture here comes from desert fogs, which form when warm air condenses over the cold ocean.

Some deserts in central Asia and Australia lie in continental interiors, so damp ocean air loses most of its moisture before it can reach them.

Desert climates and wildlife vary drastically. Hot deserts like the Sahara are warm year-round and rain is scarce.

An elf owl (the world's smallest owl) peeking out its nest in a saguaro cactus



Stay hydrated

1 Don't ration water or drink only when you're thirsty. Instead fend off dehydration by reducing water loss through sweat. Loosen clothes, keep your mouth closed and avoid unnecessary movement.

Find shade

2 Keep cool and conserve water by resting near large rocks and other natural shade. Create shelter beneath a tarpaulin or blankets, and move around at dawn or dusk when it's cooler.

Seek water

3 If you're stranded without water, look for birds circling over waterholes. Follow trails or roads, and dig near thirsty plants like willows. Wait for rescue beside water if possible.

Build a fire

4 Temperatures plunge in hot deserts at night. Fires keep you warm, create smoke to attract rescuers, give out light and cooking heat, and help fend off scorpions and other critters.

Save yourself

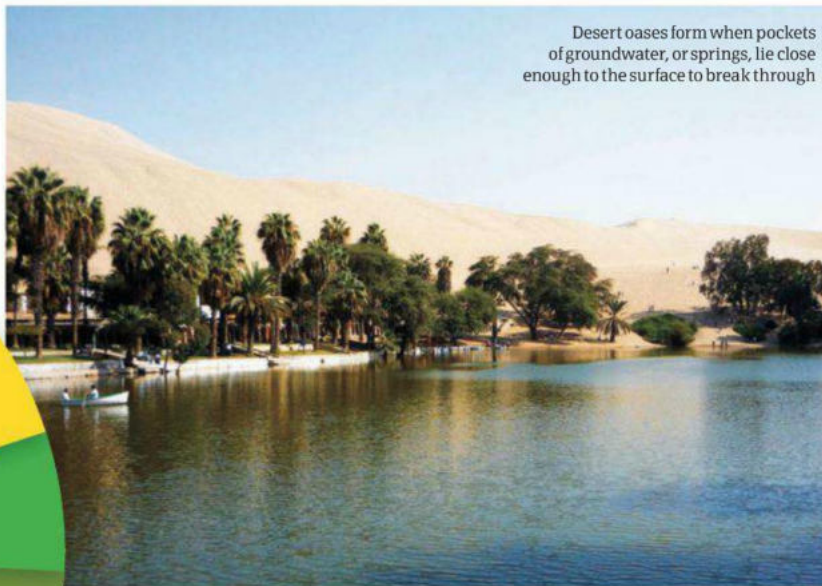
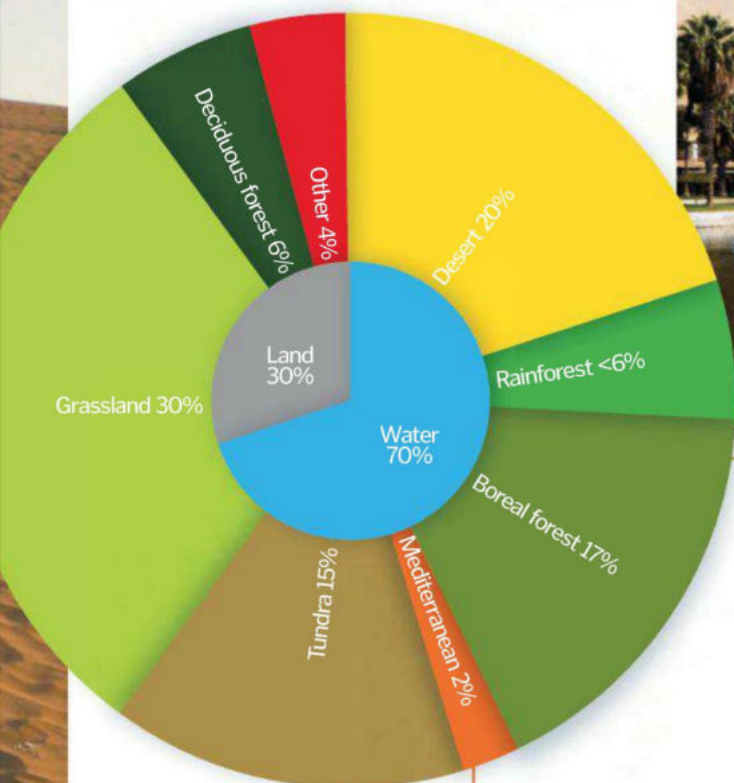
5 Spell out messages to attract low-flying planes using rocks or logs. Blow a whistle, light fires, signal by flashing sunlight off a mirror, or write notes for rescuers to find.

DID YOU KNOW?

Solar panels covering just 0.3 per cent of the Sahara would generate enough clean energy to power Europe

Earth's makeup

Of the 30% of Earth that is land, desert accounts for one-fifth of that terrain



Desert oases form when pockets of groundwater, or springs, lie close enough to the surface to break through

Explore desert landscapes

Dunes aren't the only desert terrain. Learn about salt pans, oases, wadis and more

Mesas and buttes

Flash floods wear away the bare sides of plateaus where soft sedimentary rocks lie beneath hard lava. Isolated flat-topped hills called mesas and buttes are left behind.

Canyon

Desert canyons form over millions of years. Rock, sand and water carried down wadis by flash floods cut deep channels into a plateau.

Plateau

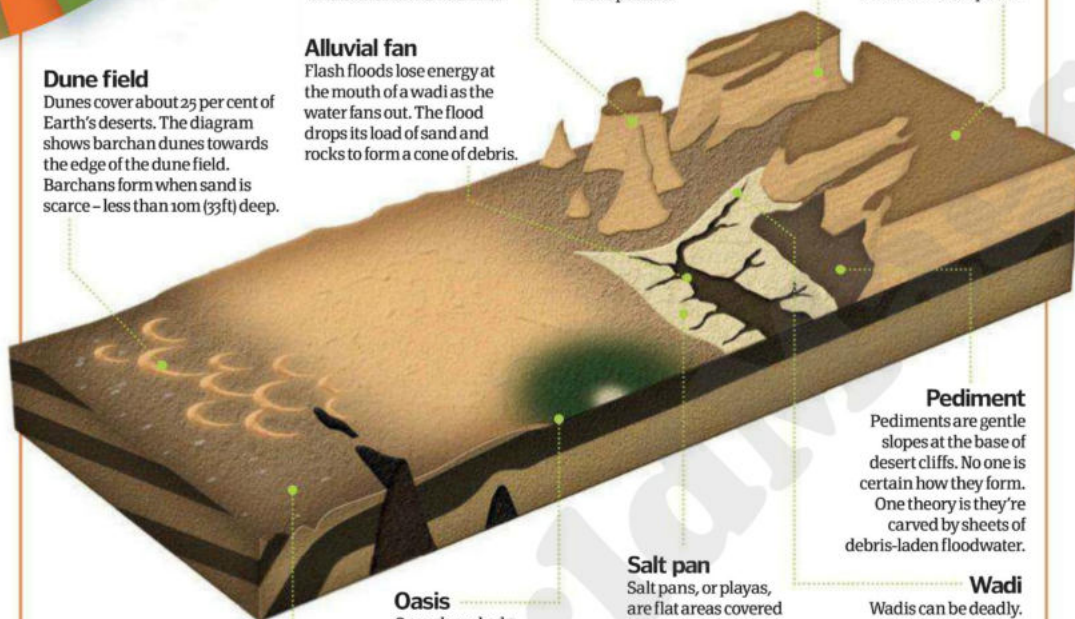
Plateaus are large flat highlands that rise more than 457m (1,500ft) above their surroundings and have at least one steep side.

Alluvial fan

Flash floods lose energy at the mouth of a wadi as the water fans out. The flood drops its load of sand and rocks to form a cone of debris.

Dune field

Dunes cover about 25 per cent of Earth's deserts. The diagram shows barchan dunes towards the edge of the dune field. Barchans form when sand is scarce – less than 10m (33ft) deep.



Pediment

Pediments are gentle slopes at the base of desert cliffs. No one is certain how they form. One theory is they're carved by sheets of debris-laden floodwater.

Wadi

Wadis can be deadly. These riverbeds are usually dry, but can flash flood in minutes after heavy rain. The flood possesses enough power to carry large boulders and sweep people away.

Salt pan

Salt pans, or playas, are flat areas covered with salt and dried-out lake beds. Water evaporates faster than the lake refills by rainfall leaving salt and minerals behind.

Oasis

Oases have lush vegetation and often surround a spring. They are fed by underground rivers or water-filled rocks that sit close to the surface.

Rocky desert

Nearly 75 per cent of deserts are stone-covered or bare rock plains. Rainfall, wind, temperature and rock type affect how the desert looks.

Temperatures can reach 49 degrees Celsius (120 degrees Fahrenheit) during the day, but at night can plunge to -18 degrees Celsius (-0.4 degrees Fahrenheit). Clear skies allow heat to escape after sunset and small mammals forage at dusk. Plants include ground-hugging shrubs with leathery leaves.

In semi-arid deserts, like the US Great Basin's sagebrush, temperatures rarely fall below ten degrees Celsius (50 degrees Fahrenheit) or rise above 38 degrees Celsius (100 degrees Fahrenheit). Spiny plants like the creosote bush thrive here.

Close to cold ocean coasts, desert summer temperatures rarely rise above 24 degrees Celsius (72 degrees Fahrenheit) and yearly rainfall can be 13 centimetres (five inches). Plants have roots close to the surface to collect rain and fleshy, water-storing stems. Some toads remain dormant in burrows for months between rainstorms.

Desert ecosystems are damaged by things like off-road vehicles, drilling and mining. Higher temperatures due to climate change could threaten drought-adapted wildlife by increasing fires as well as drying out waterholes.

The spotted hyena is the largest of the three subspecies and is a very bold and resourceful scavenger



Life at the extremes

Facing scorching days, freezing nights and little water, hot deserts are hard to survive, but lots of wildlife still call them home...

Camel

Camels can drink an incredible one-third of their body weight in ten minutes, and store water by diluting their blood. They chew thorny plants with their thick lips. Their fat-filled humps both insulate them against the beating Sun and serve as a source of energy during food shortages.



Addax

Addaxes are Earth's most desert-adapted antelopes. Broad, flat-soled hooves stop them sinking into sand, while their brown coats turn white in summer to reflect sunlight and keep them cool. Addaxes search the Sahara for grasses and shrubs to eat, which provide all the water they need.

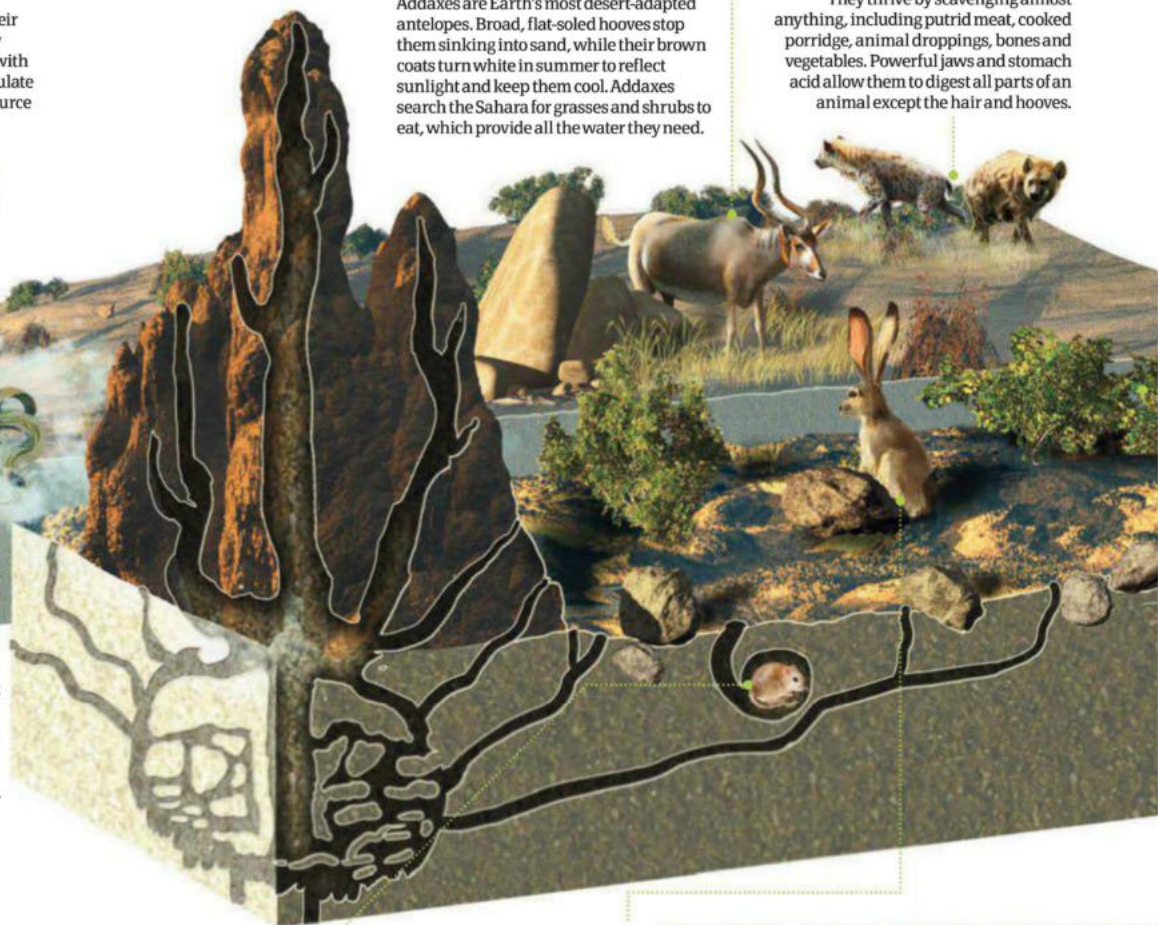
Spotted hyena

Spotted hyenas are Africa's commonest large carnivore and live in semi-desert.

They thrive by scavenging almost anything, including putrid meat, cooked porridge, animal droppings, bones and vegetables. Powerful jaws and stomach acid allow them to digest all parts of an animal except the hair and hooves.

Welwitschia plant

Welwitschia are leathery succulent plants that rely on desert fog and dew for water. Found along the Namib Desert coast where no rain falls some years, they collect fog through numerous tiny pores on their leaves. Their long taproot can reach underground water too.



ON THE MAP

Where are the world's greatest deserts?

- 1 Sahara Desert, northern Africa
- 2 Arabian Desert, Arabian Peninsula
- 3 Kalahari and Namib Deserts, south-west Africa
- 4 Patagonian Desert, Argentina, South America
- 5 Great Basin Desert, United States
- 6 Australian Desert, Australia
- 7 Gobi and Taklamakan Deserts, Mongolia and China, central Asia
- 8 Atacama Desert, Chile and Peru, South America
- 9 Karakum Desert, Turkmenistan, central Asia
- 10 Thar Desert, India, Asia

Kangaroo rat

Kangaroo rats never need to drink. Their kidneys extract water from their food, which includes insects, grass, leaves and seeds from creosote bushes. To make dry seeds succulent, they store them in humid burrows to absorb water.

Black-tailed jackrabbit

Black-tailed jackrabbits are hares, not rabbits. They have black-tipped ears, which are a huge 12.5cm (5in) long; these lose heat to keep the animal cool. Jackrabbits shelter from the Sun in hollows beneath shrubs or grass and forage in the cool of evening.



1. BIGGEST



Antarctica

Size: 7 million km² (15.4 million mi²)
The world's coldest continent is Earth's biggest desert. It has less than 5cm (2in) of rain each year.

2. DRIEST



Atacama

Rainfall: <1.5cm (<0.59in)
No rain falls in the Atacama some years. In some sections, one 3.4mm (0.13in) shower is six times the average yearly rainfall.

3. HOTTEST



The Sahara

Temperature: 58°C (136°F)
Earth's hottest temperature was recorded at Al Aziziyah, northern Libya. Air temperatures were hot enough to pasteurise an egg!

DID YOU KNOW? People-sized penguin fossils, aged around 35 million years old, have been found in the Atacama Desert

Roadrunner

Roadrunners aren't ditzzy or blue, but are well-named as they sprint from danger at 32km/h (20mph). To save energy, they cool down at night and they warm up by turning their backs to bathe in morning sunlight.



Saguaro cactus
The saguaro is North America's largest cactus and can reach 15m (50ft) tall and weigh six tons. Cacti are botanical water balloons. Expandable wooden ribs support each plant's pulpy body allowing it to inflate to store rain. To reduce water loss, they have no leaves and spines protect them from predators.

Creosote bush

Creosote bushes in the Mojave Desert could be Earth's oldest living plants – perhaps 11,700 years old. Creosote grows in US deserts and can survive two years without rain. Small, waxy leaves reduce moisture loss and drop off during dry periods. These shrubs only flower after rain.



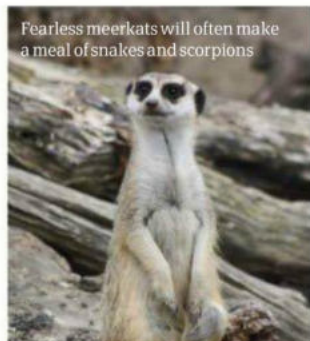
Thorny devils are found throughout Australia's vast arid interior

Thorny devil

Thorny devils catch morning dew and rainwater in tiny grooves between the scales on their belly and legs. They can gather as much as 1g (0.04oz) during a rainstorm. The lizard gulps to move water from the channels up into its mouth.

Meerkat

Meerkats absorb heat on cold mornings by exposing their dark bellies, which have little hair. Like many desert animals, they get all their water from food. Dark circles around their eyes reduce glare from the Sun, while a special membrane across their eyes keeps out any sand in the air.



Fearless meerkats will often make a meal of snakes and scorpions

Sahara Desert ant

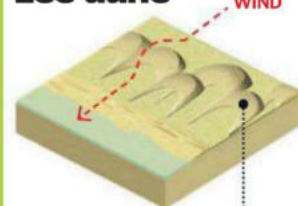
One of Earth's most heat-tolerant insects, these ants withstand surface temperatures of 60°C (140°F). Long legs raise their bodies above hot ground and they sprint to minimise sunlight exposure. Desert ants count their footsteps to avoid getting lost instead of leaving a chemical trail, which would evaporate.

"Thorny devils catch morning dew and rainwater in grooves between scales on their belly and legs"

Sand dunes

Almost 99 per cent of Earth's active dunes are in deserts, but how do they form?

Lee dune



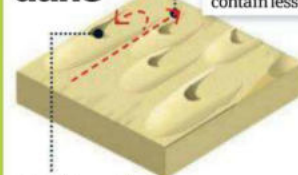
Sand ridge

Wind eddies when it blows over and around a rock. Windblown sand is dropped on the downwind side.

Horns

The downwind-facing horns race along faster than the centre as they contain less sand.

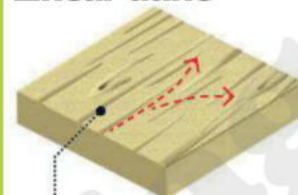
Barchan dune



Swirling wind

The downwind side of the dune is steepened by eddies formed when wind overshoots the dune crest.

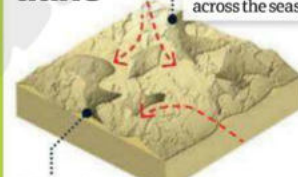
Linear dune



Wind changes direction

Linear dunes form when steady winds blow from two different directions. Sand moves parallel to the crest.

Star dune



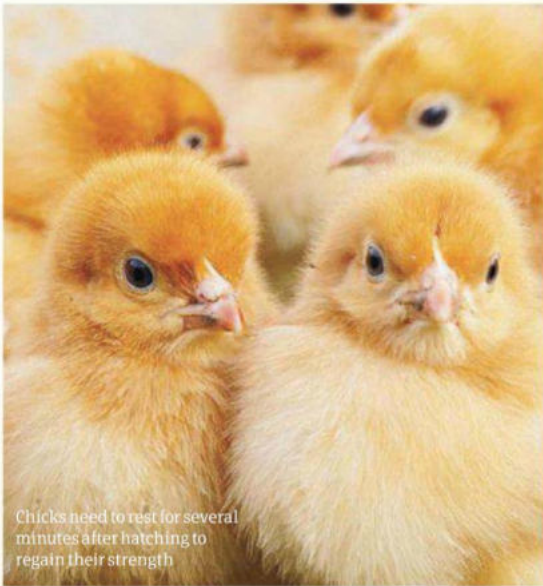
Seasonal winds

Star dunes form when strong winds rotate through many directions across the seasons.

Giant dunes

Star dunes can reach 500m (1,640ft) tall. The rotating winds pile sand instead of blowing the dune along.

"An egg can still be laid whether or not it has been fertilised by a male"



Chicks need to rest for several minutes after hatching to regain their strength



Hen anatomy

Even unfertilised eggs still undergo the same initial formation process

1. Ovary

The female's egg cell, the oocyte, is released from the ovary into the oviduct – a process called ovulation.

2. Layers

As the oocyte travels along the oviduct it is covered in layers of protective substances, including albumen.

3. Shell

The final layer to cover the egg is calcite, which forms a hard, protective outer shell. Eggshell colour is determined by genetic pigment deposition inside the oviduct.

4. Embryo

A fertilised egg will now develop a chick embryo inside. Unfertilised eggs will simply get laid with yolk and albumen.

5. Contractions

When the hen is laying her egg, the intestine and inner part of the cloaca are blocked shut by the emerging egg. A series of careful muscular contractions helps the egg pass through the cloaca.

6. Cloaca

The cloaca is the section at the end of the oviduct, which turns itself inside out when the egg is released, keeping the almost sterile egg away from any faecal matter leaving the intestine.

7. Vent

This is the common opening used not only for reproduction and the release of an egg, but also for the excretion of urine and faeces. Two separate ducts lead to this orifice: one for reproduction and outgoing eggs, and the other for waste only.

How do chickens lay eggs?

The debate over which came first – the chicken or the egg – still rages. However, we can tell you how a chick emerges from an egg...



Hens lay no more than one egg per day as the process of laying an egg is governed by the presence of sunlight. The lack of natural light during the winter months means that even fewer eggs are laid during this time of the year. Humans can, however, 'trick' chickens into laying despite the limited sunlight by adding artificial light (such as a light bulb) to the coop.

The laying process starts when light entering the hen's eye activates a photosensitive gland (the pineal gland) positioned nearby. Once stimulated, this gland triggers a process that leads to the release of an egg, or oocyte, from the hen's ovary. An egg can still be laid whether or not it has been fertilised by a male, but only fertilised eggs can develop into chicks.

The orifice through which the egg leaves the hen is called the vent. Though this hole also forms the outlet for waste by-products (ie urine and faeces), there is a valve called the cloaca which separates the oviduct from the intestine.

1. HEATING



Fried egg

Egg white contains mainly water and protein. Heat excites the proteins and this breaks down bonds, enabling the proteins to bind with one another.

2. BEATING



Meringue

Just like heating causes bonding, so does adding air. Whisking exposes one end of the molecules to air and the other to water causing the proteins to align and fuse.

3. MIXING



Mayonnaise

Oil and water don't mix, due to differing polarities. However, an emulsifier like egg yolk attaches one end of an egg's protein strand to water and the other end to the oil, binding the two.

DID YOU KNOW? The chicken is now believed to be the closest living relative of the T-rex



In a natural environment, chickens live in a flock and take a communal approach to caring for eggs

Feeling broody?

A hen will keep laying around one egg per day until she has a dozen eggs – also known as a clutch. If the eggs are collected by humans each day, however, the hen will continue to lay eggs in an effort to produce a clutch of 12. Once an egg has been laid, the hen will leave the nest, causing the embryo to cool and suspending its development. As long as the nest temperature stays warm enough, an embryo can remain suspended for up to two weeks until the hen has managed to lay a full clutch. Once she has produced a clutch of eggs the hen will stop laying and start brooding, which involves sitting on the eggs for three weeks while the embryos develop. This means the eggs should all hatch at the same time.

Inside the egg

What goes on under the shell?

Embryo

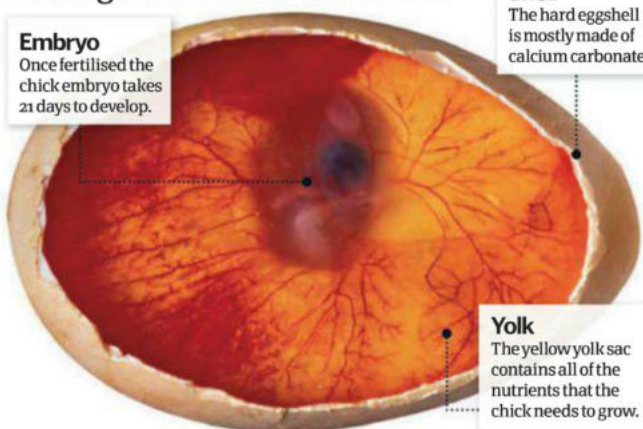
Once fertilised the chick embryo takes 21 days to develop.

Shell

The hard eggshell is mostly made of calcium carbonate.

Yolk

The yellow yolk sac contains all of the nutrients that the chick needs to grow.



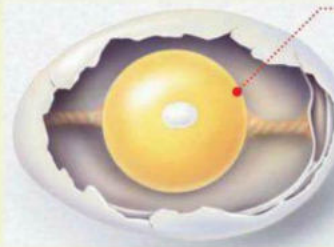
Embryo development

How a fertilised yolk transforms into a chick

The chick starts out as a single cell that divides and forms a hollow disc on the surface of the yolk. This yolk is then released into a spiralling oviduct tube. As it travels down the oviduct it builds up a number of layers, including a vitelline membrane directly surrounding the yolk, and two layers of viscous white albumen divided by a structural fibrous layer. Lower in the oviduct tube the eggshell layer develops around the yolk, protecting it and giving it form. When the egg is expelled from the body so begins the following 21-day period of embryonic development...

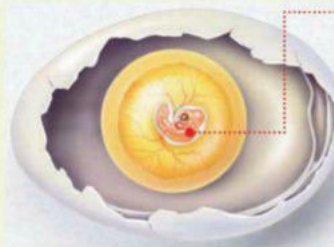
DAY 1 Yolk

The fertilised yolk contains all the nutrients needed to sustain a developing embryo – the darker the yolk the better. By the time a fertilised egg is laid, many cells have already started to divide in the germinal disc on the surface of the yolk. A structure called a chalaza made of albumen located inside the egg holds the yolk in place, anchoring it to either end of the shell and protecting it. Over time the chalaza gets twisted as the yolk moves around.



DAY 4 Heart

After a couple of days the heart will have formed and begun to beat independently. At this stage the head, eyes and even the beginnings of its legs will have begun to form, and by day four the embryo's reproductive organs will start to develop. The thin membrane separating the albumen from the eggshell grows as the contents of the egg shrinks, creating a tiny pocket of air. This air space will eventually enable the chick to start to breathe.



DAY 10 Skeleton

After ten days the embryo will still be featherless but it will start to draw calcium from the shell in order to grow its tiny skeleton, enabling the bones of the legs and spine to develop. The claws and beak will also begin to form.



DAY 16 Preparing to hatch

The leg and wing bones will become increasingly advanced and strong. Internal organs are now almost fully developed too. By now the beak will also be upturned towards the pocket of air inside the shell, ready to break through the soft inner membrane and take its first breath.

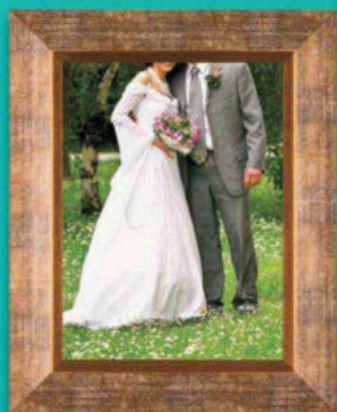


DAY 20 Breakthrough

Between day 16 and hatching, the chick's beak will have penetrated the inner membrane to access the air inside the shell and the lungs will have begun to function. The yolk sac has now been absorbed into the chick's body cavity. The chick pecks at the outer shell using a horny projection on its beak called the egg tooth. The second stage involves twisting its body and chipping away at the shell, until it can push the top of the shell off with its head.



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In 1963, the biggest ever wasp nest was discovered on a farm in New Zealand. It measured a staggering 3.7 metres (12.2 feet) in length and was 1.8 metres (5.9 feet) in diameter.

DID YOU KNOW? The Andean condor is the national animal of Colombia



While wasps have earned something of an unpopular reputation, they are actually invaluable for keeping pests in check

What's inside a wasp nest?

Find out how this predatory insect constructs its papery home



When a queen wasp comes out of hibernation she will begin looking for a site to build a nest. She starts by creating a petiole, which forms the main stalk from which the rest of the nest will hang (like the petiole stalk that attaches a leaf to its stem). To produce the material from which the nest is made wasps collect weathered wood and plant matter with their powerful mandibles and chew it up. The papery matter is combined with saliva to generate a paste ideal for nest construction – even in awkward crevices and cavities, such as a roof's eaves.

The next job for the queen is to begin construction on a small framework of downward-facing hexagonal cells that form the main body, which is used for brood rearing. After building the first cell at the end of the petiole she adds another six around that, and so on until the nest has grown to about the size of a walnut.

Inside each cell the queen lays an egg to create a starter brood of worker females. Eventually these hatch into larvae and the queen will stop nest building to spend about a month looking after these young wasps. Once they are mature enough to fend for themselves, the young wasps then take on the role of workers and resume construction. The world's biggest recorded wasp nest reached a length of 3.7 metres (over 12 feet). With the workers now active, the queen can concentrate on egg-laying and rearing larvae.

Core

The heart of the wasp nest is where not only the structure itself begins, but the colony too, as the queen lays the first of many broods of eggs.

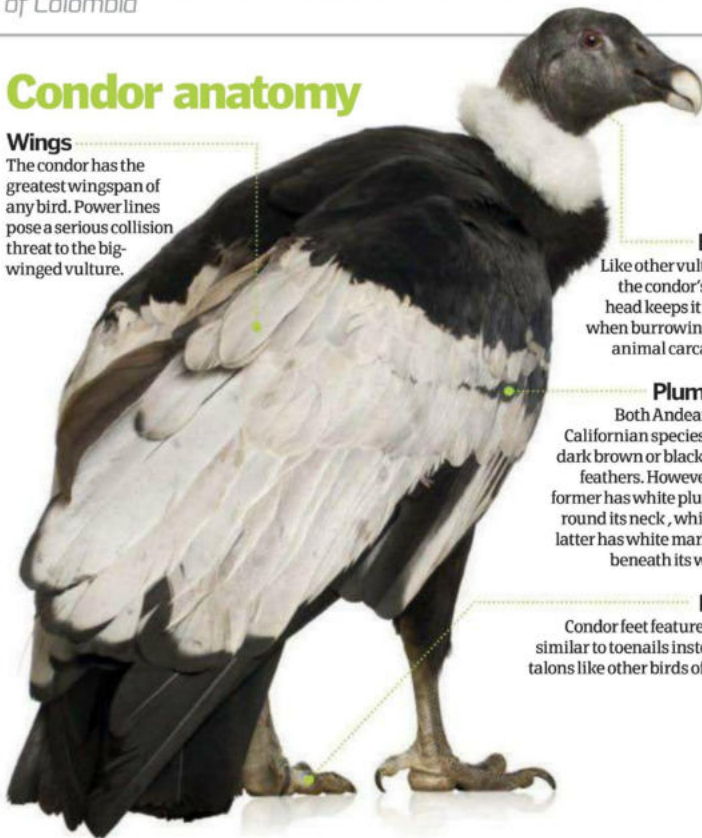


© SPL

Condor anatomy

Wings

The condor has the greatest wingspan of any bird. Power lines pose a serious collision threat to the big-winged vulture.



Bald

Like other vultures, the condor's bald head keeps it clean when burrowing into animal carcasses.

Plumage

Both Andean and Californian species have dark brown or black body feathers. However, the former has white plumage round its neck, while the latter has white markings beneath its wings.

Feet

Condor feet feature nails similar to toenails instead of talons like other birds of prey.

How the condor survives

Discover the largest flying bird on the planet today



The condor, which falls into the New World vultures category, is a huge flying scavenger native to the wooded alpine and mountainous regions of the western Americas.

Being a carnivore, whose diet consists of the carcasses of bison and other large mammals, the condor relies on its ability to soar over vast distances with the help of a huge wingspan and the use of thermal columns. Thermals are masses of rising hot air that help carry this vulture to great heights – sometimes 4,600 metres (15,000 feet) at speeds of up to 88 kilometres (55 miles) per hour – so they can spot carrion across the widest areas. Despite being built for soaring over huge distances at great height, the condor doesn't have well-developed flight muscles and only

really flaps to take off. Indeed, after a particularly heavy meal a condor may not be able to take off at all for a while.

Condors pair up for life and do not take new partners even after a mate has died. The condor nests at high altitudes to protect the egg (they only lay one at a time) from predators, but the egg is at risk from the extreme mountain weather. Parents share incubation duties and, once hatched, the chick will be raised by the parents for two years.

Both the Andean and Californian species of condor are endangered. While according to the IUCN Red List the Andean condor is currently near-threatened, the Californian condor is critically endangered and worsening due to a number of factors, including the growing danger of accidental ingestion of lead shot from carcasses that have been killed and left by hunters.

The statistics...

Condor

Type: Bird

Genus: *Vultur gryphus*

Diet: Carnivore

Average life span in the wild:

Up to 60 years

Weight: 15kg (33lb)

Body size: 1.2m (4ft)

Wingspan: 3.2m (10.5ft)

The Grand Prismatic Spring

What makes it so hot and why is it so colourful?



Yellowstone Park, Wyoming, became the world's first national park when President Ulysses S Grant signed it into law in 1872. It's not hard to see why the government wanted to preserve this area of great natural beauty, especially with features like this: the world's third-largest hot spring.

The Grand Prismatic Spring is Yellowstone's largest at 90 metres (295 feet) wide and 50 metres (164 feet) deep, and works like many of the park's hydrothermal features. Water deep beneath the ground is heated by magma and rises to the surface unhindered by mineral deposits. As it bubbles to the top it cools and then sinks, only to be replaced by hotter water coming from the depths in a continuous cycle. The hot water also dissolves some of the silica in the rhyolite rocks in the ground, creating a solution that's deposited as a whitish siliceous sinter onto the immediate land surrounding the spring.

So what makes all the pretty colours? That's not due to chemicals, anyway. The iridescent pigments are caused by bands of microbes – cyanobacteria – that thrive in these warm to hot waters. Moving from the coolest edge of the spring along the temperature gradient, the *Calothrix* cyanobacteria lives in temperatures of no less than 30 degrees Celsius (86 degrees Fahrenheit), can live out of the water too and produces the brown pigment that frames the spring. *Phormidium*, meanwhile, prefers a 45–60-degree-Celsius (113–140-degree-Fahrenheit) range and creates the orange pigment, while *Synechococcus* enjoys temperatures of up to 72 degrees Celsius (162 degrees Fahrenheit) and is yellow-green. The deep blue colour seen in the centre is the natural colour of the water and is too hot for most bacteria, although it's suspected that *Aquifex*, a microbe that thrives in near-boiling water, lives off the hydrogen gas dissolved in the emerging Grand Prismatic Spring's waters.



AMAZING VIDEO!

SCAN THE QR CODE
FOR A QUICK LINK

Check out this spring's neighbour, Old Faithful

www.howitworksdaily.com



DID YOU KNOW? The Grand Prismatic Spring discharges an average 2,548 litres (560 gallons) of water every minute

In terms of size, the Grand Prismatic Spring is only beaten by the Frying Pan Lake (New Zealand) and the Boiling Lake (Dominica)



© Milla Zinkova

Can I drink it?

No. While there's no problem with the water itself, the cyanobacteria that give the Grand Prismatic Spring its characteristic colouration can cause all sorts of problems if ingested. They produce a range of dangerous compounds including neuro- and hepatotoxins that cause vomiting, rashes, numbness and worse: long-term liver damage, nervous disorders and even cancer. This isn't exclusive to humans; cyanobacteria are a common sight all over the world and, where they bloom in prolific numbers, they pose a serious threat to local ecosystems. That's one reason why the area immediately surrounding the spring is so barren.

"They have teeth 8cm (3in) long and their echolocation system allows them to find prey in complete darkness"

How killer whales hunt

To merely call them the wolves of the sea is a gross underestimation



Killer whales aren't whales (they are more closely related to dolphins) and it's not fair to call them killers

either. There are no confirmed cases of fatal attacks on humans by killer whales in the wild. But they are incredibly intelligent hunters – probably second only to humans. Killer whales, or orcas, can swim at 56 kilometres (35 miles) per hour (or 30 knots), they have teeth eight centimetres (three inches) long and their echolocation system allows them to find prey in complete darkness. But what really sets them apart is their ability to plan, improvise and work as a team.

Orcas live in loose family groups called pods, of five to seven individuals. In the wild their life span can be 60 years or more but the infant mortality rate is very high; up to half will die before they are seven months old. This is mainly due to the difficulty of finding enough food. Killer whales are mammals and their warm-blood metabolism uses a lot of energy. An adult needs 230 kilograms (510 pounds) of food a day.

To feed this appetite, some subspecies prey on schools of fish by circling below them and releasing a stream of bubbles to confuse them. Others have learned that they can catch sharks by flipping them on to their backs to induce a sort of panic stun, known as tonic immobility. The killer whales that hunt among the Arctic sea ice catch seals and walrus by knocking them off ice floes into the water (see 'Hunting as a pack' boxout).

These are not purely instinctive behaviours; orcas will teach their young, often deliberately catching and releasing a seal several times to allow them to practise hunting. In 2005 scientists observed a killer whale regurgitating fish at the water's surface to lure seagulls down before catching the birds. Four other orcas subsequently learned this tactic.



In April 2012 the first ever all-white orca – named Iceberg due to his 2m (6.6ft) dorsal fin – was spotted off the coast of eastern Russia



Dorsal fin

Provides roll stability when swimming; the male has a larger fin that can reach 2m (6.6ft) tall.

Blowhole

The blowhole closes when relaxed, so a killer whale must consciously think to open it and breathe.

Saddle patch

Grey rather than white for the other patches. The shape varies between individuals and is used by scientists for identification.

The makeup of a maritime mammal

Melon

This lump of fatty tissue acts like a lens to focus the sound waves from the orca's echolocation clicks.

Teeth

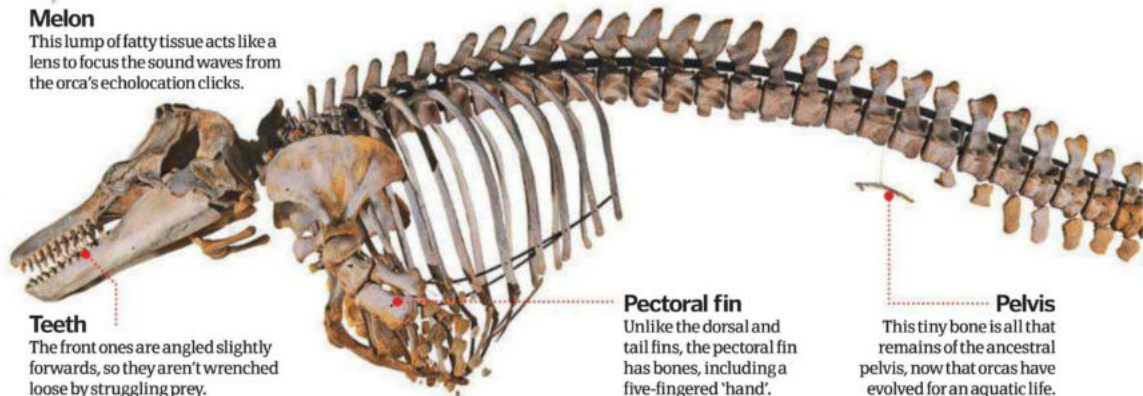
The front ones are angled slightly forwards, so they aren't wrenched loose by struggling prey.

Pectoral fin

Unlike the dorsal and tail fins, the pectoral fin has bones, including a five-fingered 'hand'.

Pelvis

This tiny bone is all that remains of the ancestral pelvis, now that orcas have evolved for an aquatic life.





DID YOU KNOW? Killer whales have been found as far as 160km (100mi) inland in rivers in the USA and Canada

The statistics...



Killer whale

Genus: Orcinus

Type: Mammal

Length: 7-10m (23-32ft)

Diet: Carnivore (eg fish, seals)

Weight: 6 tons

Life span in wild: 50-80 years

Status: Threatened

Tail fluke

Most of the thrust from the tail is generated on the upstroke of the two flukes, not the downstroke.

Median notch

Helps to reduce turbulence in the orca's wake, and thereby keep drag to a minimum.

HUNTING AS A PACK

1. Lunging

Initially, a single orca may try to beach itself on the ice floe, snatch the seal and roll off.

2. Repositioning

If that doesn't work, the killer whales will twist and push the floe away from other ice in the vicinity.

3. Spotter

One orca now positions itself behind the seal and blows through its blowhole to signal the attack run.

4. Formation swimming

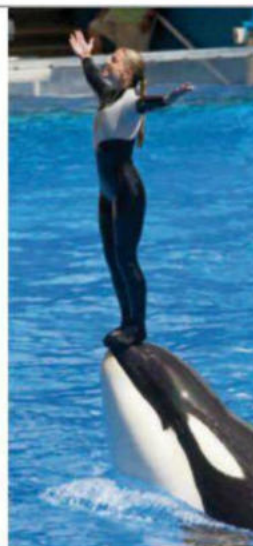
The other orcas then swim as fast as possible to generate a large bow wave in front of them.

5. Wipeout

At the last moment, they duck under the ice and the wave often washes the seal towards the waiting spotter.

6. School of whales

A young orca watches the co-ordinated attack to learn this hunting technique.



Is keeping killer whales in captivity a good idea?

There are 42 orcas currently held in captivity in aquariums and sealife parks around the world. Since 1990, almost all of these have been born in captivity. Orcas put on an impressive show because of their huge size and striking appearance. But they are also extremely intelligent and they can be trained to perform spectacular jumps and a wide range of tricks.

Most zoo animals have longer life spans than in the wild but the reverse is true for orcas. Lack of company from other orcas and the limited size of their tank mean they rarely live beyond 25 years. The male orca's huge dorsal fin nearly always loses rigidity and flops over after a few years in captivity. This is a permanent structural change to the fin cartilage and may be due to insufficient exercise or too much time spent swimming at the surface.



ON THE MAP

Where are the largest killer whale populations?

- 1 Norwegian coast
- 2 Coast of Iceland
- 3 Canadian Arctic and Greenland
- 4 Coast of British Columbia, Washington and Oregon
- 5 Sea of Japan
- 6 Southern Ocean, around Antarctica



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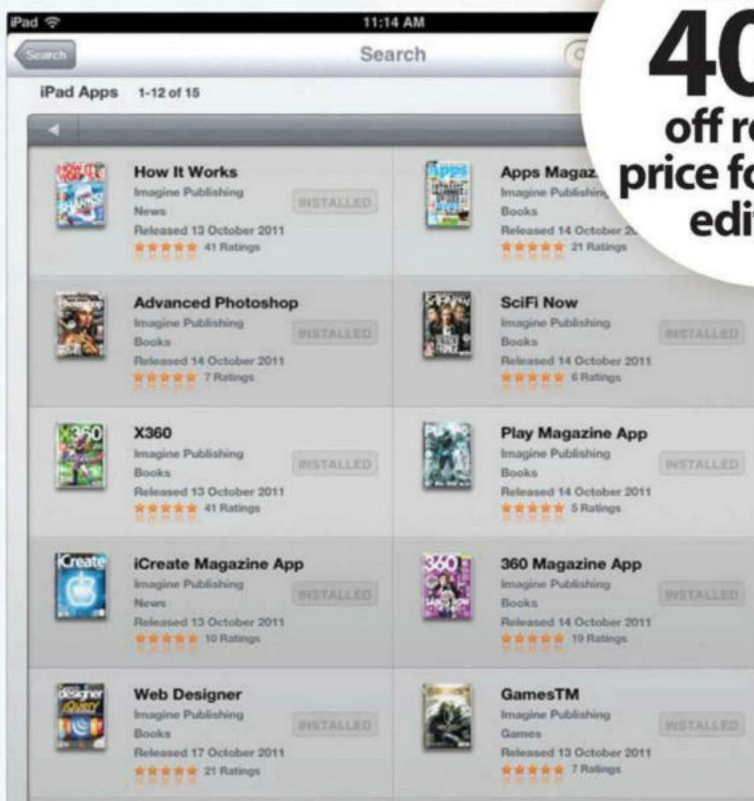
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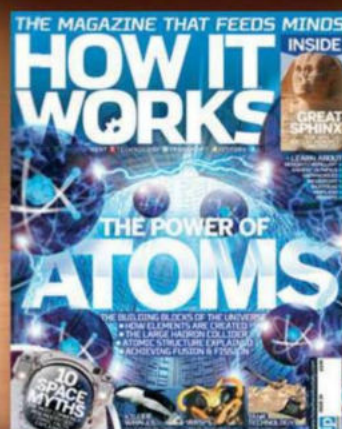
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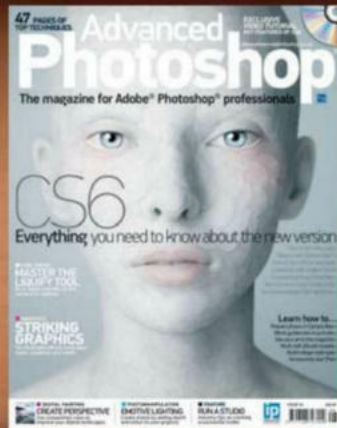
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Origins of the Olympic Games



Welcome to... HISTORY

In honour of the fast-approaching Olympic Games coming to London this summer, we have put together a comprehensive guide to the origins of the international celebration of sport. Elsewhere, we look at how Egypt's Great Sphinx was built, as well as some inventions that totally revolutionised their respective fields.



78 Landau coaches



79 The Great Sphinx



80 Record players

- 74 Ancient Olympics
- 78 First washing machine
- 78 Landau carriages
- 79 The Great Sphinx
- 80 Record players



LEARN MORE



A-Z of the Ancient Greek Olympics



The modern Olympic Games may look very different, but the underlying ethos hasn't changed in millennia



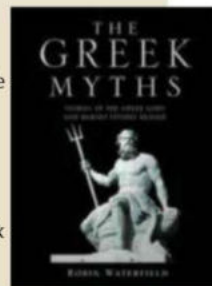
The ancient heroic code was, as the epic poet Homer put it, 'to strive always to be the best, superior to others';

hence the modern Olympic motto, 'Faster, Higher, Stronger'. The Ancient Greek world consisted of about 1,500 economically independent city-states, dotted around the coastlines of the Mediterranean and Black Seas, and these states were often at war with one another. Nevertheless, they all thought of themselves as Greeks, and they invented sport, and international festivals such as the Olympic Games, as opportunities to test themselves against their peers without shedding blood – or not too much of it, anyway! The games were even protected by a sacred truce so that competitors and spectators could

travel in safety. So, every four years, thousands made their way to the Peloponnese, the southern peninsula of Greece, where Olympia was situated. Like today, athletes competed for a combination of individual and national glory. The origins of the games are lost in the mists of time: like other games in Ancient Greece, the Olympic festival probably began in celebration of the death of a local hero – perhaps Pelops himself, after whom the Peloponnese is named ('the island of Pelops'). But the Greeks themselves said that the games began in 776 BCE, and took that year as the start of the first Olympiad. The year 2012 begins the 30th Olympiad of the modern era (since the competition restarted in 1896), but, technically, it begins the 697th Olympiad. *

The Greek Myths

The Greek Myths is a new retelling of the timeless myths and legends of ancient Greece by renowned classicist Robin Waterfield and his wife, writer Kathryn Waterfield. Together they weave a vivid tapestry of the most unforgettable stories in all human history. A catalogue of Greek myth in art through the ages, and a notable work of literature in its own right.



Politics and sport

1 The unhappy involvement of politics is not only a modern phenomenon. The ancient organisers too sometimes tarnished the Olympic spirit by excluding rival city-states.

The marathon

2 There was no marathon race in the ancient Olympic Games – and the story of Pheidippides' run from the Battle of Marathon to Athens in 490 BCE is only a legend.

Winning women?

3 Although women were not allowed to participate in the ancient games, they could be registered as Olympic victors – by putting up the money for a winning chariot team.

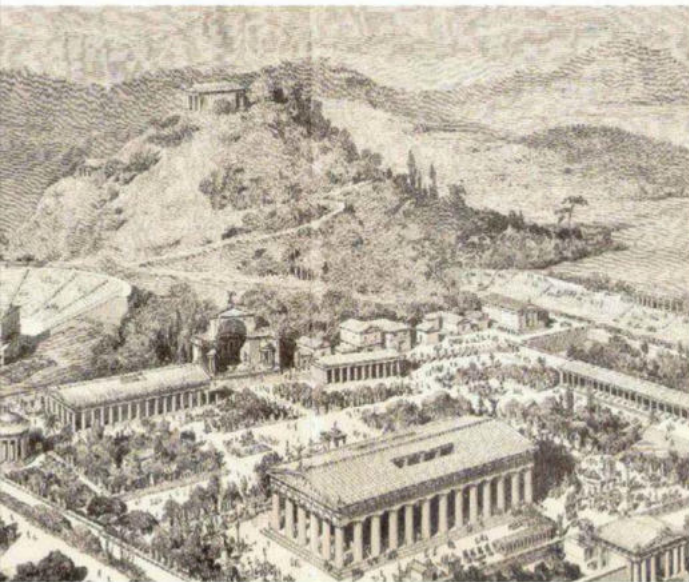
War games

4 The Summer Olympics were cancelled due to war in 1916, 1940 and 1944, and the same happened in ancient times too. However these Olympiads still count for dating purposes.

Pierre de Coubertin

5 The modern Olympics were the brainchild of educator Baron Pierre de Coubertin, who felt he was resurrecting the bygone ideal of 'a sound mind in a sound body'.

DID YOU KNOW? All the participants in the ancient Olympics, for the first several centuries of the competition, were aristocrats



An artist's impression of the ancient site of Olympia, which sits at the foot of the Hill of Kronos

Ancient Olympia

The sacred enclosure and its landmarks

The Olympic Games, which were held from 776 BCE to 393 CE, were first and foremost a five-day religious festival dedicated to the glory of Zeus. Within the sacred enclosure – the Altis – were the spaces employed for the athletic competitions and the god's worship, as well as for the ceremonies that took place during the festival. By the Classical period numerous buildings populated the area, and the stadium and hippodrome (not shown below) were enhanced. Most of what we see today has been excavated, in a joint venture between the Greek Archaeological Service and the German Archaeological Institute, since 1936.

Great Altar of Zeus

So many animals were sacrificed here that the ashes, congealed by fat, came to reach a height of 7m (23ft)!

Altar of Demeter Chamyne

Opposite the judges' stand, the only married woman permitted at the Olympics, Demeter's priestess, perched here to view the contest.

Stadium

Numerous events besides the all-important footraces were staged here; its embankments could accommodate up to 40,000 spectators.

Gymnasium

Here athletes practised javelin and discus throwing, and even running, in a roofed colonnade the length of the stadium.

Prytaneion

This building held the victors' feast and the goddess Hestia's sacred fire, used to light all of the altars.

Swimming pool

This unique feature of Olympia, used for refreshment not events, was about half the size of a modern 'Olympic' pool.

Palaistra

With covered colonnades and special-use rooms, it was used for 'heavy' events, eg wrestling, as well as for practice.

Temple of Olympian Zeus

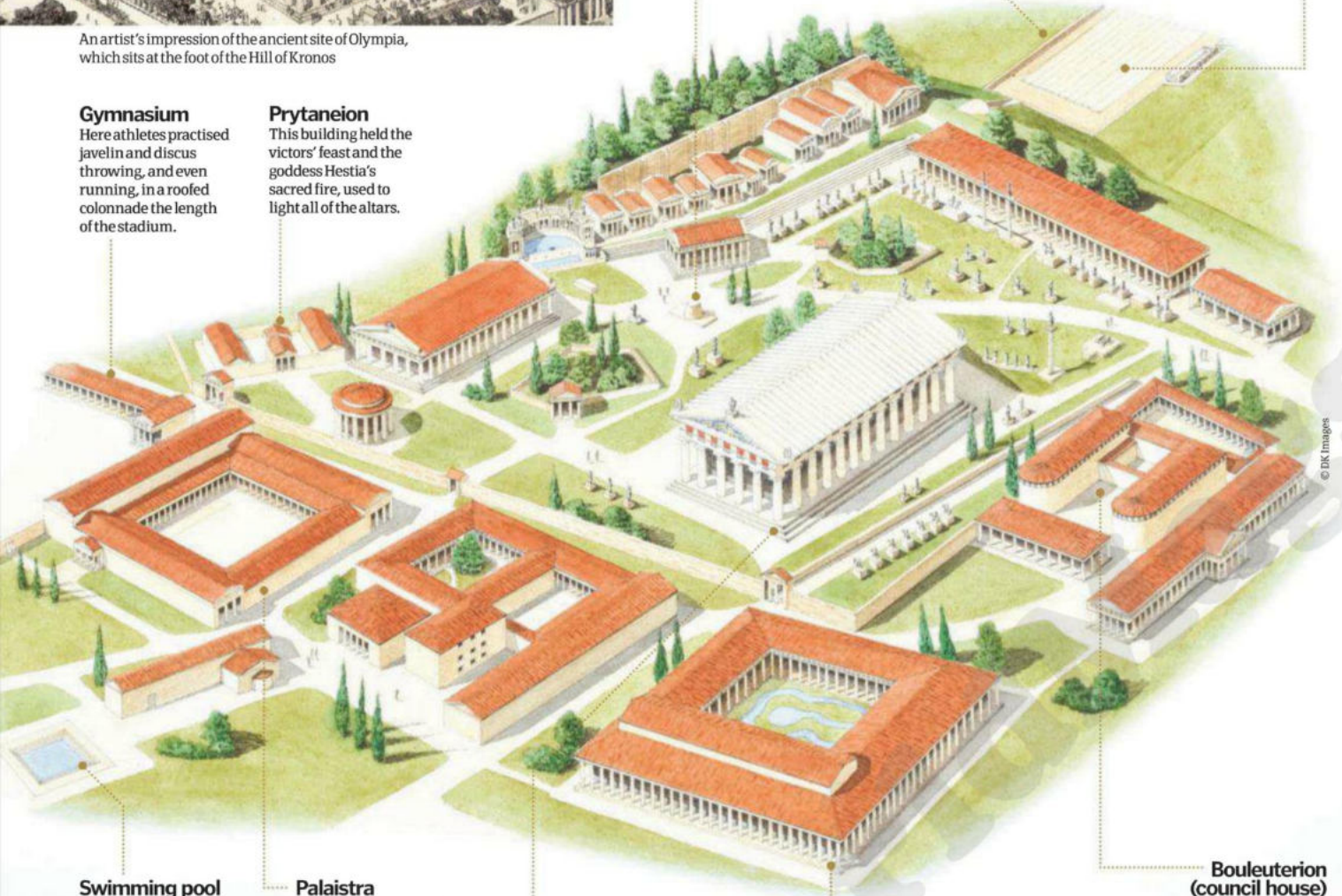
The heart of Olympia, it housed the gold and ivory statue of enthroned Zeus, which was 13m (43ft) tall.

Leonidaion

The largest building on the site was a 'hotel' donated in the 4th century BCE by Leonidas of Naxos.

Bouleuterion (council house)

The administrative and archival centre of the festival, and the place where competitors and judges swore their oaths.



© UK Images



"The only events were those considered suitable training for warfare"

A is for... **Altis**

This is the enclosure, sacred to Zeus, where the Olympic festival took place. For the Olympic Games were a religious festival, not just a sporting event, and the central event of the five-day games was a hecatomb – the enormously lavish sacrifice of 100 oxen at Zeus's altar.



B is for... **Boxing**

Although similar to modern-day boxing, the rules were not quite the same, above all because there were no rounds. Competitors just slugged it out, with their hands wrapped in strips of leather, in a ring formed of spectators, until – maybe hours later – one man was knocked out or collapsed.



K is for... **Chariot-racing**

Chariot-racing was extremely dangerous, and the wealthy owners trained slaves for all the equestrian events. The two events involving chariots were held in the hippodrome, which was about 600 metres (1,970 feet) long, and wide enough to allow up to 40 chariots to race at one time.

D is for... **Diet**

Ancient athletes recognised the importance of eating special foods for energy and muscle development; they even argued about whether one should abstain from sex while training. An athlete's diet was richer in meat than the normal Greek diet.

E is for... **Events**

The only events were those considered suitable training for warfare: boxing, wrestling, pankration (a brutal form of ancient martial art with almost no rules), four running races, the pentathlon, chariot-racing and several equestrian events.

F is for... **Flame**

A conspicuous aspect of the modern Olympics is the ceremonial lighting at Olympia of the Olympic flame. This is said to commemorate Prometheus's mythical gift of fire to mankind, but in fact it had no ancient counterpart, and was first introduced for the 1928 Olympics held in Amsterdam.

G is for... **Gymnasium**

The gymnasium was simply a practice area. The actual events were held outdoors, in the blazing heat of a southern Greek summer, but the Greeks were sensible enough to want to practise indoors. The Olympic gymnasium provided the athletes with all the facilities they needed for both training and relaxation.



H is for... **Heracles**

The ultimate strongman, Heracles (who was known as Hercules to the Romans), is credited in one story with founding the Olympic Games. He filled his lungs and sprinted until he needed to draw breath again, and that spot marked the end of the stadium. Apparently, he could hold his breath for approximately 200 metres (660 feet).

I is for... **Inscriptions**

The Altis gleamed with statues in bronze and marble of famous athletes or dignitaries. But, positioned so that athletes would see them as they entered the stadium, there was also a terrace of statues inscribed with the names of cheats, and put up at their expense as a punishment.



J is for... **Jugglers**

The ancient Olympics were not just an occasion for sport. In a carnival-like atmosphere, poets and orators declaimed, peddlers and prostitutes hawked their wares, and jugglers and other kinds of performers offered entertainment. Spectators mingled in their thousands with contestants and their trainers, slaves and priests, alongside representatives from every walk of life.

K is for... **Kallipateira**

Having no surviving male relatives to train her son, Kallipateira of Rhodes trained him up herself, and defied the strict ban on female presence at the Olympics by disguising herself as a man. Her deception was discovered, however, when she leapt for joy at her son's success and exposed herself.

L is for... **Leni Riefenstahl**

For the Berlin Olympics of 1936 Adolf Hitler had the filmmaker Leni Riefenstahl carve the five interlocked Olympic rings onto a stone, to suggest that this was an ancient symbol, but in fact it was invented in 1913, to represent the five main regions of the world.



776 BCE

This is the date chosen by Ancient Greek historians as the start of the first Olympiad.

393 CE

Christian Emperor Theodosius I publishes an edict banning the Olympic Games and other pagan practices.

1875

Scientific excavation of ancient Olympia begins, under German archaeologist Ernst Curtius (right).



1896

The first modern Olympics are held, for sound symbolic reasons, in Athens, Greece (right).



1900

For the first time, women are allowed to compete in the games; they are still awaiting full equality with men.

DID YOU KNOW? The heart of Pierre de Coubertin, founder of the modern Olympics, is buried in a plinth by the ancient site

M

is for... **Milo**

Milo of Croton (a Greek city in southern Italy) was perhaps the most famous athlete of the ancient world. He was a



wrestler, and he achieved the astonishing feat of winning in six successive Olympics, once as a boy and five times as an adult.

N

is for... **Nudity**

For all the track and field events, the male contestants were nude. Penises were tied back against the body with a leather string to minimise discomfort.

There were few female spectators, and homoerotic admiration was encouraged by the gratuitous practice of rubbing athletes' bodies with olive oil until they gleamed.

"Cheating was rare: the few events did not readily lend themselves to it, though officials could potentially be bribed"

O

is for... **Oath**

The spirit of the ancient Olympic oath was exactly the same as its modern counterpart – except that nowadays the oath is not

administered over a slice of raw boar meat. Essentially, the athletes swore to play fair, and the judges to judge fairly and not to divulge information about any of the contestants.

P

is for... **Pentathlon**

The pentathlon consisted first of the three events that were peculiar to it: discus, javelin and long jump. If there was no clear champion after the first

three events, the contestants were narrowed down by a sprint; if there was still no clear winner, then it was decided by a wrestling match.

Q

is for...

Quadrennium

The Olympic Games were held, as now, every four years. The other most famous games – at Delphi, Nemea

and Corinth – were four-yearly or two-yearly festivals, and were spaced so as not to clash with the Olympics, and so that athletes could attend a major festival in any given year.

R

is for... **Ribbons**

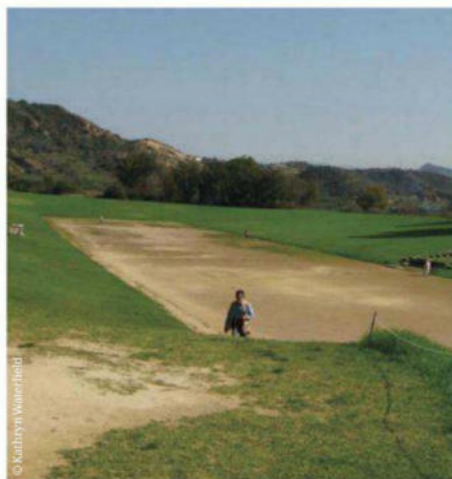
The prizes at the Olympic Games in Ancient Greece were no more than ribbons – bands, intertwined with sprigs of wild olive, to wreath the heads of the victors. The winner gained enormous prestige, and that was all – though that was sometimes enough to bring him fame and fortune back home, perhaps in the political arena.

S

is for... **Stadium**

The sandpit was the venue for wrestling, the hippodrome for equestrian events, and the rest were held in the stadium, whose grassy banks could seat 40,000 spectators.

The four footraces were: one- and two-stade sprints, a 20-stade slog and a two-stade race run in armour.



T

is for... **Training**

The Ancient Greek lifestyle guaranteed a basic level of fitness, but athletes also practised their specific events and cross-trained through dancing, for

instance. All contestants also trained for the month preceding the games in the Olympic gymnasium.

U

is for...

Underhand dealings

Cheating was rare: the few events did not readily lend themselves to it, though officials could potentially be bribed. Despite having a range of medications, the use of performance-enhancing drugs doesn't seem to have been an issue.

V

is for... **Victory**

The Greeks were not sportsmen in our sense: victory was all, and coming second counted as defeat. Nor were they interested in world records:

accurate measurement was difficult, so the focus was on beating your rivals in the immediate event.

W

is for...

Women

Except for a single priestess and unmarried girls, women were not allowed into the ancient Olympics. But an all-female festival was organised at Olympia, just before or after the male games. Sacred to Hera, the goddess wife of Zeus, these games consisted of no more than a few footraces.



X

is for... **E'xcellence**

Competition was a major part of an aristocrat's life – hence the importance of the Olympic Games. Only one's peers counted: Alexander the Great quipped,

when asked if he'd enter the sprint, "Only if my opponents are also kings."

Y

is for... **Youth**

Olympic events fell into three age categories: boys (aged 12-15), youths (16-18) and men (over 18). Success at Olympia could radically change a boy's

life. He seemed to be destined for greatness, and back home he would be groomed to play a major part in his city's political life.



Z

is for... **Zeus**

Pheidias's 13-metre (43-foot)-high gold-and-ivory statue of the enthroned god, housed in his temple at Olympia, was one of the

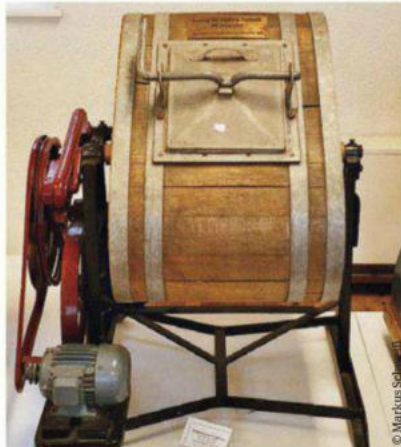
Seven Wonders of the Ancient World. Zeus's altar, north of the temple, supposedly marked the spot where he struck the site with his thunderbolt, claiming it as sacred to his worship.



"Landaus are tailored towards presenting the occupants to each other and passers-by"

The first electric washing machine

Today they are a staple appliance few of us could live without, but where did they begin?



An early 20th-century washing machine similar in design to the first commercial washer the Thor



The first mass-marketed electric washing machine was the Thor, a tumble washer produced by the Hurley Machine Company in 1908.

The machine worked by tumbling clothes with a wooden drum, in two directions, at eight revolutions per minute. The drum's rotation mechanisms were powered by a single Westinghouse Electric Company electric motor and connected together via drive belts. Most innovatively, however, the Thor featured an integrated clutch, which allowed the machine to switch revolution direction and also be held in a stationary position once power was supplied. For a closer look at the machine's inner workings see the diagram to the left.

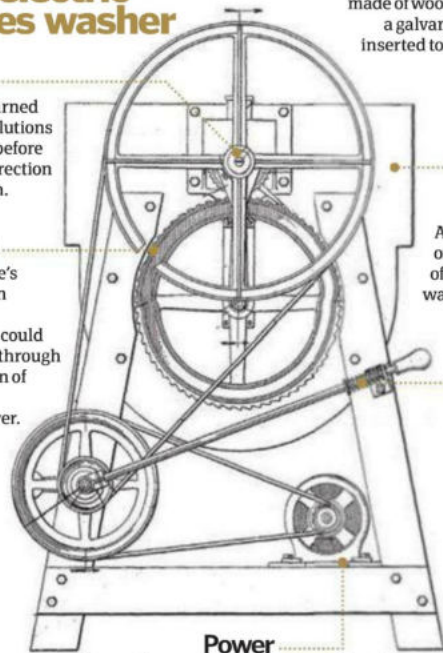
Inside the Thor electric clothes washer

Spin

The drum turned at eight revolutions per minute before reversing direction to spin again.

Wringer

The machine's chain-driven wringing mechanism could be reversed through the operation of a top-right-mounted lever.



Drum

The Thor's drum was made of wood, into which a galvanised tub was inserted to hold clothes.

Clutch

A control lever on the left side of the machine was operated to engage and disengage its clutch.

Power

Unlike modern machines, the Thor did not have an on/off switch, instead requiring users to physically disconnect its power cord to turn it off.

Landau carriages explained

What are landaus and why does the British royal family own so many of these convertible carriages?



A landau is a type of mobile coach, consisting of a four-wheeled, convertible carriage and a set of horses to pull it. It was designed in the 18th century in the German city of Landau – hence its name – and was first introduced to England at the start of the 19th century. By the mid-19th century, the landau was a common form of transport in and around cities by the aristocracy and was even adopted by the British royal family.

The landau works, principally, like any other horse-drawn carriage, with a front-centre driver controlling a set of horses to pull the four-wheeled chassis in a desired direction. The chassis is mounted to a wheelbase fitted with elliptical springs to ensure a smooth ride over cobbled or uneven terrain. What separates it from other models, however, is its unique seating design, which is tailored towards presenting the occupants of the carriage to not only each other but, critically, passers-by; this was a key feature for the rich and influential in the 19th century. This high visibility is ensured by a split convertible roof – folding down from the top-centre apex in opposite directions, a glazed full-height or half door, as well as inwardly facing, raised seats.

While today landaus have largely been made obsolete due to the invention of the motorcar, they are still used in many countries for state occasions (for example, they are commonly used to transport the Queen of England), as well as to carry tourists around historic cities like Vienna, Austria.

Door

Landaus are either fitted with a fixed full-height glazed door or, more commonly, a low-lying half door.

Horse-power

Proper landaus require at least a pair of horses to be drawn effectively; this is occasionally increased to four animals.

Seating

The dropped footwell of the landau is flanked by two opposing sets of bench-style seats.



Suspension

Landaus employ elliptical springs to cushion the lightweight chassis.

The forgotten Sphinx

1 Though Giza is known for its hieroglyphic recounting of history dating back 4,500 years, not a single inscription from this period references the Sphinx.

My Sphinx has no nose

2 There are many theories as to what happened to the Sphinx's misplaced hooter. A pervasive but inaccurate rumour is that Napoleon's soldiers blasted it off with a cannon.

Watery controversy

3 Radiocarbon dating shows the Sahara wasn't always dry. Water erosion on the Sphinx enclosure could be consistent with that caused by rainfall that would predate the 2500 BCE construction period.

Sphinx of many colours

4 It's thought that, due to evidence of red pigment on the Sphinx's face plus blue and yellow residue elsewhere, at some point the statue may have been multicoloured.

The future

5 Human activity has led to a rise in the local water table, which is seeping into the statue's porous limestone, affecting structural integrity. Pumps are in place to try and mitigate this.

DID YOU KNOW? Some say the head of the Sphinx was originally much bigger and that it was reshaped to look human later

Layout of the Giza pyramid complex

Pyramid of Menkaure

Khafre's son, Mykerinos, built the smallest of the three pyramids at Giza. Much of the complex remained unfinished, suggesting his reign was short-lived.

Satellite pyramid

Only the outlines of the foundations remain but this small pyramid held shrine artefacts.

Pyramid of Khafre

Khufu's son, Khafre, built the second tallest pyramid at Giza, although it may appear tallest due to its location on a higher section of the Giza plateau.

Great Pyramid of Giza

The largest of the pyramids is the Great Pyramid (or Pyramid of Khufu), a royal tomb that would have taken something like 20 years to construct.

Queens' pyramids

Though these monuments were built for unknown queens, it's likely one was the burial place of Khufu's mother, Hetepheres I, as a cache containing items belonging to her was discovered near the northern-most pyramid.

Queens' pyramids

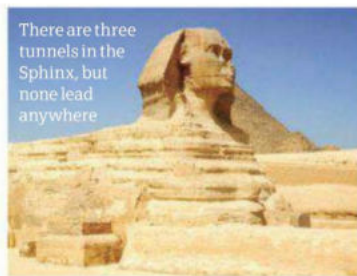
Of the three smaller pyramids to the south of the Pyramid of Menkaure only the one to the east is actually a real pyramid; the other two are stepped.

Mortuary temple

Khafre Valley Temple

The remains of the Khafre Valley Temple walls in front of the Great Sphinx are still visible today. The temple consisted of a courtyard surrounded by 24 pillars. Because of this temple's east-west axis, it's been suggested that each of the pillars represented, or marked, each hour in the day.

There are three tunnels in the Sphinx, but none lead anywhere



The Great Sphinx at Giza

Discover the answers to the mysteries surrounding the world's largest single-stone statue



The Great Sphinx is the huge monolithic statue of a human-headed lion that was carved into a single mass of limestone bedrock on the western bank of the Nile during the third millennium BCE. The Sphinx faces directly east and its stonework features once included a cobra-embellished headdress and a beard.

Though neither the Sphinx nor its principal architect were cited within the content of any hieroglyphs from the time, the 'foreman' of the project is widely regarded to be Pharaoh Khafre (c. 2558-2532 BCE), the ruler of the Old Kingdom, which was a period of early Egyptian civilisation that endured for 2,500 years. Incidentally, Khafre's father - Khufu (c. 2589-2566 BCE) - built the Great Pyramid at Giza

approximately 400 metres (1,300 feet) from where the Sphinx statue would later be carved.

Regarding the identity of the labour force, an Old Kingdom cemetery containing the tombs of some 600 possible workers and overseers was unearthed in the early-Nineties. Following that, in 1999 Egyptian archaeologist Mark Lehner found a settlement dating back to the reign of Khafre, capable of accommodating between 1,600 and 2,000 people - a rather convenient Sphinx construction workforce, perhaps?

4,500 years ago, before bronze and iron were prevalent, the available tools for this colossal undertaking would have included copper implements and stone hammers. Modern reconstructions, using similar stone and ancient-style tools, have estimated

that the Sphinx could have been constructed in just three years with 100 people chipping away at a rate of 0.03 cubic metres (one cubic foot) per week.

Using the huge excavation of stone quarried away from the Sphinx enclosure (the pit in which the statue sits), the labourers were also able to construct the nearby Sphinx Temple. Each block that was removed from the Sphinx statue site could have weighed up to 200 tons and would have been transported on rollers.

Until the Thirties, when an archaeologist called Selim Hassan excavated the lower half of the statue, the Great Sphinx remained buried up to its shoulders by sand. Today it stands proud alongside the other monuments of Giza as a testament to the engineering skill of the Ancient Egyptian civilisation.

The statistics...



Great Sphinx

Height: 20m (65ft)

Length: 73.5m (241ft)

Width: 6m (20ft)

Build date: c. 2500 BCE



"Records work in a very similar, if a more tangible, way to the latest playback devices"

Record players

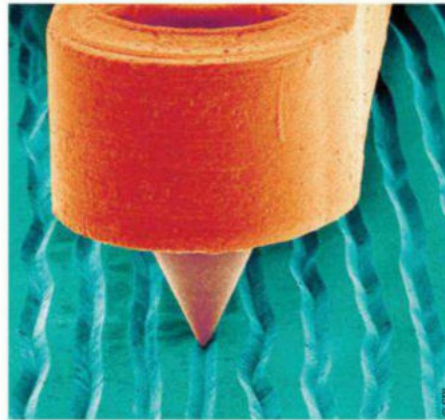
How sound is recorded and replayed from vinyl



Vinyl records are the audio storage media of yesteryear. You can think of them as MP3 players that simply store sound using a different system: older hard disk drives use magnetism to store this information, reading and writing using an arm that sweeps back and forth across spinning magnetic plates. Flash-memory music players (read: iPods and their contemporaries), meanwhile, make use of transistor technology to store digital music, while compact discs have tiny pits pressed into the silver layer by a laser, which can be read by a CD player.

Records work in a very similar, if a more tangible, way to the latest playback devices, though the same principles behind 19th-century phonographs can be seen at work in modern turntables. The tiny grooves in the record vibrate a crystal in the stylus (needle) at the end of the arm as it moves across the record's surface. The resulting microscopic jolts move a metal bar that squeezes a piezoelectric crystal, generating an electric signal. The signal is fed to the amplifier that interprets it, then sends it out to the speakers which replicate the original sound.

Today's records are made of vinyl, pressed from a metal 'mother' that is cut using highly specialised machines. But even though the recording is of a much higher quality, you can still spin the turntable by hand to hear the record play without any intervention from modern technology.



A shot taken by a scanning electron microscope of a stylus running along a groove in a record

Record

The record is pressed from a 'biscuit' of vinyl, though they were first made of shellac, the resin from the Indian lac bug.

This is a replica of Edison's tinfoil phonograph.
Inset: Thomas Edison



Birth of the gramophone

In 1877, over a century before the dawn of digital music recording, Thomas Edison discovered that by attaching a needle to the diaphragm of a telephone receiver, a visual representation of the sound could be drawn when the needle vibrated along a cylinder covered in tinfoil. By attaching a horn and rotating the cylinder by hand, the sound could then be reproduced. Edison put his work on the phonograph

on hiatus while he focused on electricity. In the meantime, Emile Berliner stepped in to create a more practical machine that used flat black discs, but could only play and not record. This was the gramophone and its records could be mass-produced via Berliner's Gramophone Company. The basic format for sound recording remained the same up until the Eighties, when cassette tapes became standard.



Record mat

A simple piece of textured rubber, but incredibly important as it stops the record from slipping on the turntable.

Motor

Powers the turntable via either a belt-driven or direct drive system.

Stylus

Tipped with a tiny diamond or hard mineral, the needle moves within the grooves on a record.

Cartridge

This is a plastic housing for the stylus that converts the vibrations from the contact with the record into electrical signals.

John Lennon and Yoko Ono's *Double Fantasy* album sold for over half a million in 1980. Why? It was owned by Lennon's assassin, Mark Chapman.

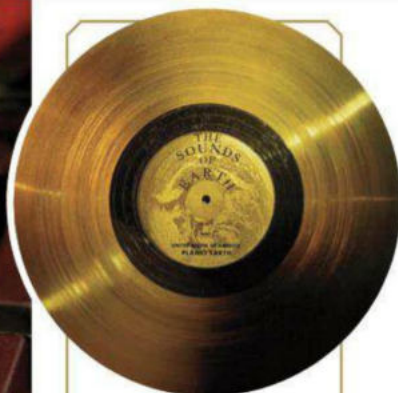
DID YOU KNOW? The first recording of a human voice was made in 1860 by Édouard-Léon Scott de Martinville

From disc to music

How It Works looks inside a record player and highlights the key components

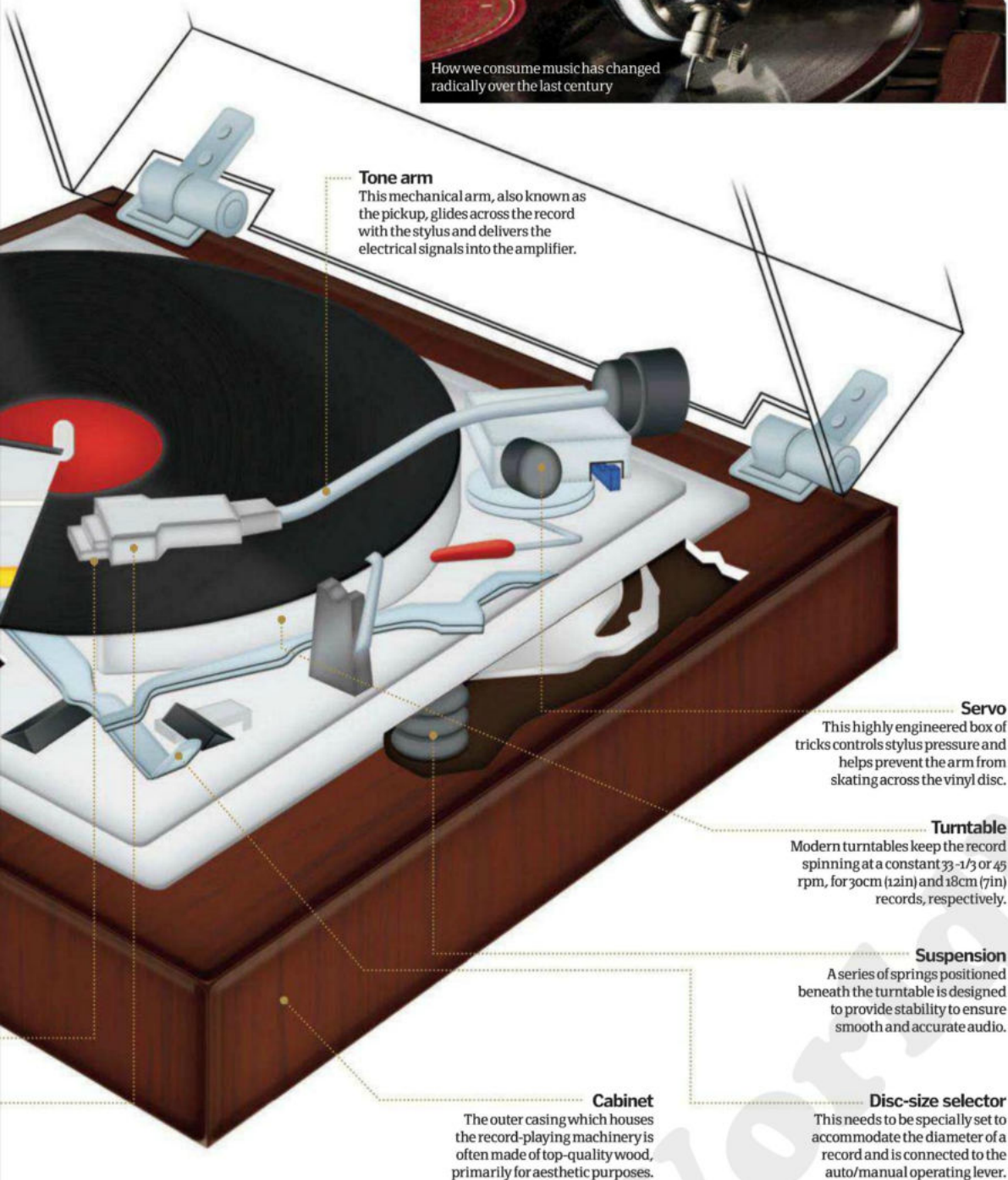


How we consume music has changed radically over the last century



World's most-famous record

Probably the most-recognised record in the world (and beyond) is the Golden Record that was placed aboard the Voyager 1 and 2 spacecraft. It is a 30-centimetre (12-inch) copper phonograph plated with gold and on it is recorded sounds, music and greetings from Earth in 55 languages, including: Beethoven's Fifth Symphony, "Hello from the children of planet Earth" in English and the sound of crickets and frogs. It is encased in an aluminium jacket and includes a needle and cartridge along with instructions for any intelligent extra-terrestrial life that happens upon Voyager on how to play the record. The record is designed to be played at 16-2/3 revolutions per minute – half the speed of the 33-1/3 standard for a commercial 12-inch vinyl. Since its launch in 1977, Voyager 1 has travelled nearly 18 billion kilometres (11 billion miles), making the Golden Record one of the few manmade objects to have left the solar system.



Tone arm

This mechanical arm, also known as the pickup, glides across the record with the stylus and delivers the electrical signals into the amplifier.

Servo

This highly engineered box of tricks controls stylus pressure and helps prevent the arm from skating across the vinyl disc.

Turntable

Modern turntables keep the record spinning at a constant 33-1/3 or 45 rpm, for 30cm (12in) and 18cm (7in) records, respectively.

Suspension

A series of springs positioned beneath the turntable is designed to provide stability to ensure smooth and accurate audio.

Cabinet

The outer casing which houses the record-playing machinery is often made of top-quality wood, primarily for aesthetic purposes.

Disc-size selector

This needs to be specially set to accommodate the diameter of a record and is connected to the auto/manual operating lever.

BRAIN DUMP

Because enquiring minds want to know...

MEET THE EXPERTS

Who's answering your questions this month?

Vivienne Raper



Vivienne is a freelance science journalist writing about subjects as varied as golfing technology and planes fuelled with chip oil. Before becoming a writer, she worked as a geophysicist.

Shanna Freeman



Shanna has been writing for most of her life. When not researching a complex subject like how the cosmos works, she's wrangling a toddler, and at times that demands more brain power!

Rik Sargent



Rik is an outreach officer at the Institute of Physics where he works on a variety of projects aimed at bringing physics into the public realm. His favourite part of the job is travelling to outdoor events and demonstrating 'physics busking'.

Mike Anderiesz



Mike has been a journalist and copywriter for over 15 years, writing for a range of publications and institutions including *The Guardian*, the BBC and Microsoft. His expertise lie in technology, computing and lifestyle products.

Aneel Bhangu



Aneel is a training academicsurgeon working in London. His research interests include advanced cancers and medical statistics, with his clinical interests including planned surgery for rectal cancers and emergency surgery for trauma.



Ask your questions

Send us your queries using one of the methods opposite and we'll get them answered



How does our solar system stay suspended in space?

Thomas aka Starryeyedtruth

Gravity isn't just for keeping planets in their respective orbits; it's a force that acts on all matter in the universe. That's the basis of Isaac Newton's theory of Universal Gravitation. The greater the object's mass (and the closer it is), the greater the gravitational force on other objects around it. All of the bodies in our solar system are affected by the gravitational pull of the Sun. However, the Sun is just one of hundreds of billions of stars in our galaxy, which in turn is one of more than 100 billion galaxies – all of which have gravitational pulls. All of which also move, by the way. For example, the Sun completes one rotation around the centre of the Milky Way every 230 million years or so. Einstein disagreed with Newton on gravity; his General Theory of Relativity stated that gravity isn't a force at all; but a curvature in space-time (or the 'fourth dimension'). This means that objects like the Earth are actually travelling along a straight path – because objects always seek the shortest distance between two points – but due to a curve in space-time, that straight path is spherical. There are some newer theories about gravity, but the important thing to note is that it's ultimately what holds everything together.

Shanna Freeman



What colour is a mirror?

Monica Harris

■ Mirrors were originally created by placing a transparent, greenish glass over a reflective silver backing, which is still usually visible at the edges. This is why mirrors are often perceived as silver. However, strictly speaking a mirror has no colour at all. Why? Because colours are created by the light that bounces off an object – if it looks red, that's because red is the main colour not being absorbed. A mirror, however, is designed to reflect everything and, with no colours absorbed at all, by definition, it has no intrinsic colour of its own.

Mike Anderiesz



If body temperature is 37°C, why do we feel hotter when it's 30°C outside?

Paddy Nighman

■ The cells in your body are always producing heat from the energy stored in the food we eat. This heat is needed to keep your vital organs at 37 degrees Celsius (98.6 degrees Fahrenheit) at all times. Depending on the temperature of the environment, your body can regulate the amount of heat produced and, to an extent, how much it loses.

However, if the environment temperature is around 30 degrees Celsius (86 degrees Fahrenheit), your body loses this internal heat much slower, as there is less of a temperature difference between your body and its surroundings. Nevertheless your body still needs to produce heat in order to keep you warm on the inside, so you end up feeling hot.

Rik Sargent



Why is Costa Rica's geography so good for growing coffee?

Rob Morris

■ Coffea arabica produces the finest arabica coffee beans. This shrub flourishes in Costa Rica because of the fertile soil, altitude and climate. Most Costa Rican coffee is grown in the highland valley region, Meseta Central, between 800 and 1,500 metres (2,600-4,900 feet). Here the soil is acidic and mineral-enriched by lava and ash spewed from volcanoes.

There are also two distinct seasons. The rainy season from May to November has cool, wet afternoons that promote coffee growth, and sunny mornings. During the dry harvest season, meanwhile – from around December to March – hot, sunny days aid coffee bean ripening.

Vivienne Raper



How does pepper make you sneeze?

Connie McDonald

■ Our noses are designed to repel anything that enters except air. Its three main defences are the fine nasal hairs in the nostrils, mucus and sneezes – reflex actions caused when nerve endings in the mucus membranes are irritated. Any rush of particles (eg dust) may trigger sneezes, but pepper is particularly irritating due to the substance that gives pepper its flavour. Piperine is an alkaloid that stimulates the nasal nerve endings, causing the brain to trigger muscles in the nose and throat to expel the foreign particles in a sudden burst of air.

Mike Anderiesz

Why do we have eyebrows?

Rob Zwetsloot

■ Developmentally, the eyebrows (like the eyelashes) keep moisture out of the eyes. This includes rainwater and sweat, which could be irritating in your eyes if you were running away from a predator. More importantly to the modern human being, eyebrows have taken on a key meaning for appearance and non-verbal communication. Lifting your eyebrows can express many things depending on the appearance of the rest of your face and body.

Aneel Bhangu



What led to the Irish potato famine? Find out on page 84

BRAIN DUMP

Because enquiring minds want to know...

How do salt flats form?

Find out on page 86

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

What caused the Irish potato famine?

Dele Spencer

■ The famine was caused by a fungal disease called potato blight, which came to Ireland from Mexico. Blight made the potatoes quickly rot, and since a third to one-half of peasants were dependent on the crop for food, this led to more than 750,000 deaths. But the famine was also the result of the social and political system in the 1840s. As Irish Catholics could not own land or hold a profession, the peasants resorted to growing mostly potatoes – which could be grown in large quantities on plots of rented land – to feed their families.

Shanna Freeman

Why don't Maltesers have a flat bottom?

Stuart Dickens

■ Mars has never confirmed the manufacturing process that it perfected for Maltesers back in 1937, when they were marketed as 'energy balls'. Clearly, the centres are made from a sweet, dough-like mixture and probably subjected to low air pressure to make the air bubbles expand and assume a honeycomb texture. However, from here on we have to make some intelligent guesses. The most logical solution would be that the honeycomb spheres are rolled through liquid chocolate and then down an incline – possibly rollers – so a flat surface can never form. However, with the manufacturer still refusing to reveal its secret, we can't be 100 per cent sure.

Mike Anderiesz

Where is the Bermuda Triangle and why are people said to disappear in it?

Sally Graham

■ The Bermuda Triangle is an imaginary area in the Atlantic Ocean off south-east USA. The three corners are Bermuda, Miami, FL, and San Juan in Puerto Rico, an area covering about 1.3 million square kilometres (500,000 square miles).

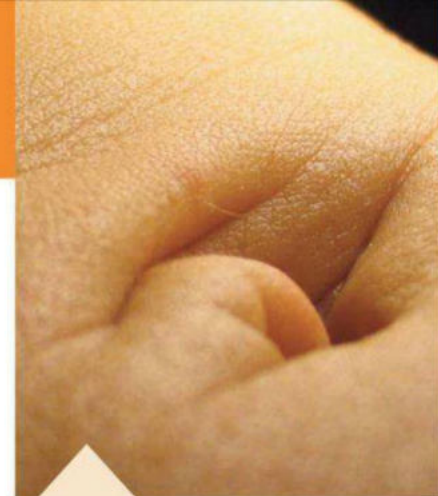
Many theories exist for the disappearance of perhaps 2,000 vessels and 75 aircraft in the region.

Among the most far-fetched are alien abductions, sea monsters or energy rays from the lost city of Atlantis. But it's likely the Bermuda Triangle is a modern myth. Marine insurer Lloyd's of London reports ships are no more likely to disappear in the area than anywhere else, and doesn't charge extra for passing through.

The myth emerged when a US Navy Avengers flight vanished without trace in 1945 after the pilot reported bizarre compass readings. A magazine article in 1964 about the doomed flight coined the name 'Bermuda Triangle', and it stuck.

Investigators have blamed pilot errors, malfunctioning heaters or compasses, treacherous reefs and bad weather on some high-profile disappearances. Any wreckage or bodies could have sunk without trace because the triangle contains some of our planet's deepest ocean.

Vivienne Raper



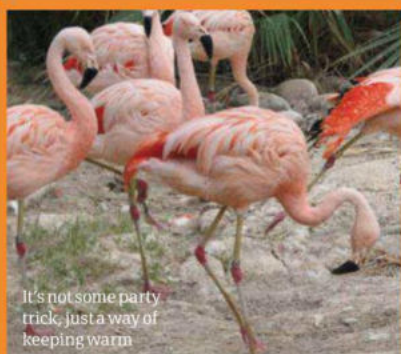
Why are there innie and outie belly buttons?

Michael Broughan

■ The umbilicus is the transition point between the blood of the foetus and its mother, through the umbilical cord that connects to the placenta. At birth, the umbilical cord is clamped a few inches from the baby, and then severed. This several-centimetre protrusion is left to shrivel and fall off, which takes a couple of weeks.

At this stage, most babies are left with an 'innie' belly button, while a minority get an 'outie.' There is no scientific explanation for this – it's probably all luck. This is very different from an umbilical hernia, where a small portion of the abdominal contents protrudes through a defect in the abdominal wall under the umbilicus; this causes a lump that bulges when you cough. In babies, these mostly disappear after a couple of years, but in adults they may need an operation. However developing one as an adult has nothing to do with the shape of your navel.

Aneel Bhangu



It's not some party trick. Just a way of keeping warm

Why do flamingos stand on one leg?

Nick Prince

■ For a long time this was a mystery. Then in 2009 two American psychologists studied a captive flamingo colony and concluded: it's about conserving heat. Although flamingos are native to tropical climates, they spend most of their time standing in cold water and their long legs mean lots of exposure to it. Tucking one leg up helps to regulate their body temperature. They usually vary which leg is up and, when the weather is warmer, they're more likely to stand on two legs.

Shanna Freeman

What is super-fast computing?

Charlie Wright

■ Super-fast computing is a buzzword yet to catch on as no one has defined exactly what it means. Most experts agree it will involve some form of 'quantum computer', but exactly how such a device is to be constructed is up for debate. Quantum computers would use the unique properties of atoms to perform calculations rather than the current model of transistors and semiconductors. There are several branches of the quantum theory being explored. Scientists in Sydney recently unveiled the world's smallest transistor, created by precisely positioning a single phosphorus atom in a silicon crystal. The consequences of this are profound; atomic semiconductors mean whole computers could be condensed and placed on a pinhead, drawing almost no power yet capable of performing calculations billions of times faster than even today's fastest supercomputer, IBM's BlueGene/L. However, it is estimated that the first fully functional quantum computer is still at least 20 years away.

Mike Anderiesz



IBM's BlueGene/L computer is currently the fastest on Earth

Do photons have mass? Find out on page 86

How do drugs affect spider webs?

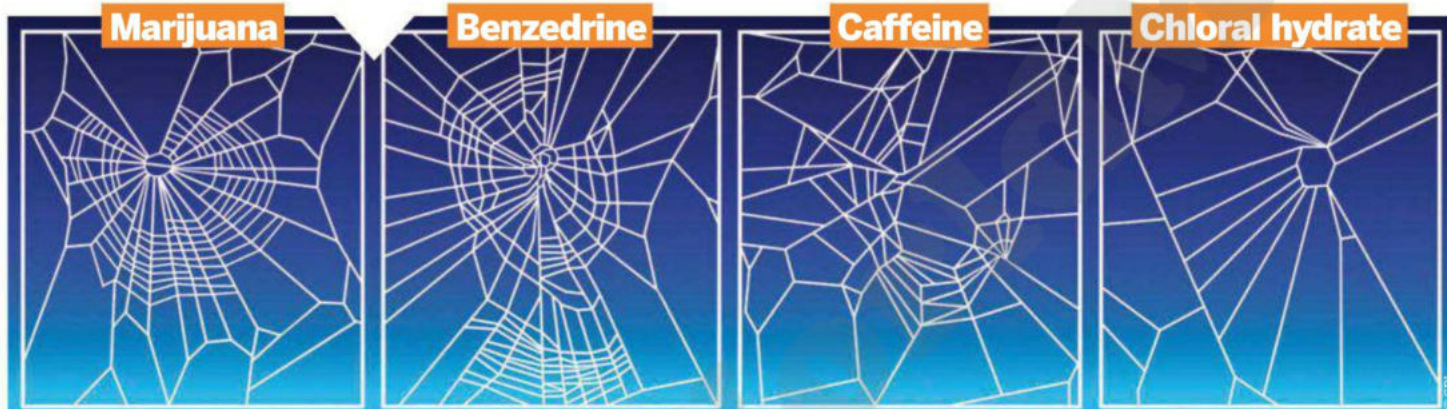
Max Philips

■ Caffeine is a stimulant that most people ingest at some point, in the form of coffee, tea, fizzy drinks or chocolate. To test some of its psychological effects, and also those of other common drugs, scientists administered them to spiders to see how they impacted on web construction.

The most famous of these experiments was conducted by NASA in the Nineties. While marijuana led to slowly spun, incomplete webs and benzedrine ('speed') led to fast-spun, poorly organised webs, it was caffeine that had the biggest effect. It almost completely stopped spiders spinning webs at all, except for a few poorly organised strands with no

structure. Caffeine is also a natural pesticide, with some plants having developed caffeine within their seedlings to protect against insects. While caffeine kills certain bugs that feed on these plants, others have adapted to it and are unaffected, such as many beetles.

Aneel Bhangu



BRAIN DUMP

Because enquiring minds want to know...

The Salar de Uyuni in Bolivia is the world's largest salt flat

What are the Deccan Traps?

Find out on page 87

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

How do salt flats form?

Darren Robertson

■ Salt flats are dried-up desert lakes. They form in closed hollows where rainfall can't drain away. In a wet climate, a lake would form but, in a desert, the water is heated and evaporates into vapour faster than it is replenished by rain. The salt and minerals dissolved in the water are left behind as a solid layer. Some salt flats are massive. Bonneville Salt Flats in Utah, USA, were formed by the evaporation of an ancient lake as large as present-day Lake Michigan. They are flat enough to be used as a raceway for setting land-speed records.

Vivienne Raper



Why is glass transparent if it's a solid?

Gail Thomson

■ When you shine light on a material, you are bombarding it with photons. Photons have a specific energy according to the frequency of light they make up. What determines how photons interact with a material is their frequency, along with how the electrons in that material are arranged. Electrons can occupy different energy levels, the lowest of which is called the ground state. In opaque materials, photons of visible light are mainly absorbed by electrons in the material. The electron then uses the photon's energy to jump to a higher energy state. In the case of glass, the amount of energy needed to raise an electron to the next energy level is higher than most materials and the photons of visible light do not have enough energy to bridge this gap, so the photons pass through.

Rik Sargent



In the late Nineties, scientists proved they could 'teleport' data using photons, but the photons were absorbed by whatever surface they struck

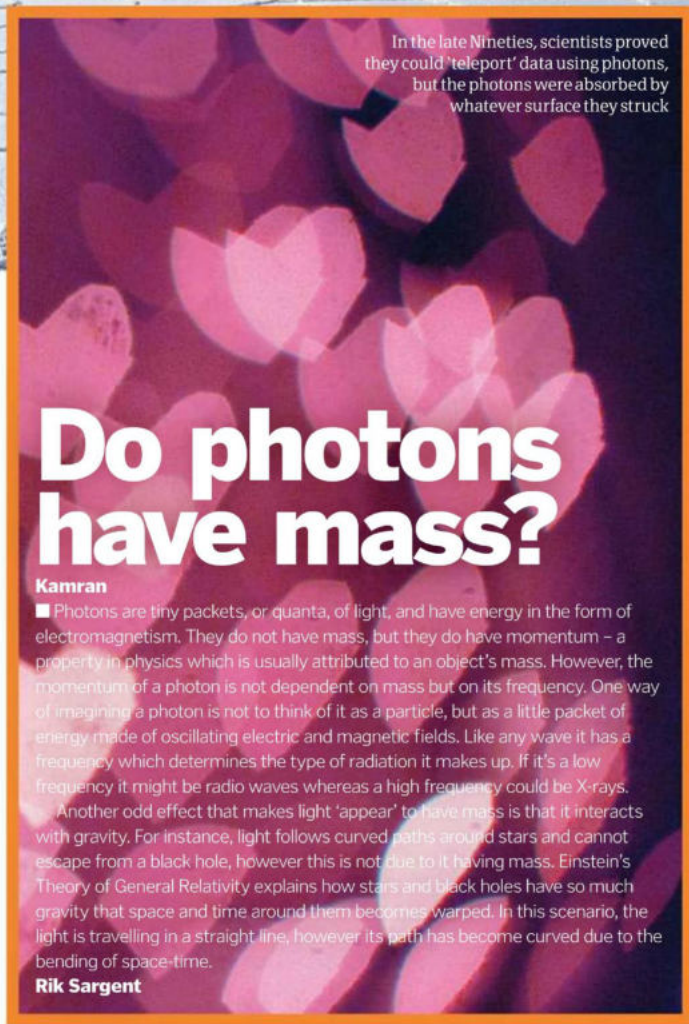
Do photons have mass?

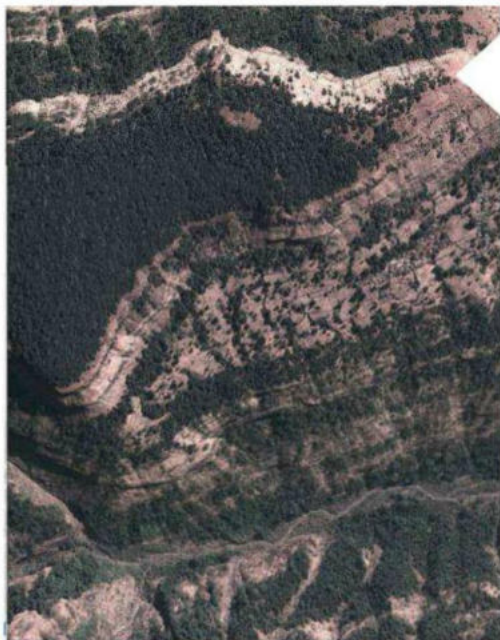
Kamran

■ Photons are tiny packets, or quanta, of light, and have energy in the form of electromagnetism. They do not have mass, but they do have momentum – a property in physics which is usually attributed to an object's mass. However, the momentum of a photon is not dependent on mass but on its frequency. One way of imagining a photon is not to think of it as a particle, but as a little packet of energy made of oscillating electric and magnetic fields. Like any wave it has a frequency which determines the type of radiation it makes up. If it's a low frequency it might be radio waves whereas a high frequency could be X-rays.

Another odd effect that makes light 'appear' to have mass is that it interacts with gravity. For instance, light follows curved paths around stars and cannot escape from a black hole, however this is not due to it having mass. Einstein's Theory of General Relativity explains how stars and black holes have so much gravity that space and time around them becomes warped. In this scenario, the light is travelling in a straight line, however its path has become curved due to the bending of space-time.

Rik Sargent





What are India's Deccan Traps?

Adam Morrish

■ The Deccan Traps are a huge stack of volcanic rocks more than two kilometres (1.2 miles) thick that cover nearly 500,000 square kilometres (200,000 square miles) of west-central India. They were formed by a massive volcanic eruption 60-65 million years ago, which spewed out enough lava to cover Earth three metres (ten feet) deep. The gases released may have changed global climate and contributed to the extinction of the dinosaurs.

Scientists blame the super-sized eruption on a hot spot, a stationary plume of super-hot buoyant rock in the Earth's interior that forms a volcano when it reaches the surface. Hot spots create island chains as the rock plates forming the Earth's surface move over them. The Deccan Traps hot spot may have led to the formation of the French island Réunion in the Indian Ocean.

Vivienne Raper



When does a hill become a mountain?

Dave McIntyre

■ Unlike with many other landforms, there is no universally accepted definition of a mountain. Many geographers state that a mountain is greater than 300 metres (1,000 feet) above sea level. Other definitions, such as the one in the Oxford English Dictionary, put the hill limit at twice that. Still others make distinctions about the degree of slope (including two degrees or five degrees). In Scotland, meanwhile, landforms with distinct summits are called 'hills' no matter what their height. But in America, there are several 'mounts' that are less than 300 metres (1,000 feet) tall. So, essentially, a hill becomes a mountain when someone names it as such.

Shanna Freeman

Why do vegetables heat up quicker than soup when they're on the same plate in a microwave?

Francois Beaujolais

■ Water molecules (H_2O) are polar molecules, as the oxygen is slightly negatively charged and the hydrogen is slightly positively charged. Due to this polarity, H_2O molecules are attracted to one another and don't move as freely as those in other materials. For this reason water has a high specific heat capacity – the amount of heat required to raise the temperature of the material by one degree Celsius (34 degrees Fahrenheit).

Vegetables contain water but soup contains much more. Water's high specific heat capacity means it needs more energy than other materials to raise its temperature, which for microwave cooking means the higher the water content in food, the longer it will take to heat up.

Rik Sargent



This is an Ames room, in which the walls, floor and ceiling have been physically distorted so the two children appear wildly different in size. Though the room appears to be square it's actually trapezoid; the right-hand corner is closer to the camera than the left

How do optical illusions affect how we perceive size?

Charlie Stubbings

■ Visual perception of colour and size is a complex and incompletely understood phenomenon. While we understand how colours are formed and how the brain interprets images, there is much more to looking at an object; there is a complex interplay between its own dimensions and its surroundings. This includes the differences in colour between the object and its background, which can make objects appear more striking or distant. Small objects of the same size that are

in colour or shape order take on a grouped appearance and patterns that are visually different to the same objects arranged in different colour/shape orders. Colour and line placement are often used to make a 2D picture seem 3D, such as in a painting, with lighter or darker objects towards the back, depending on lighting. The fashion industry has made use of this theory too; dark colours with vertical stripes are said to make you appear slimmer than bright colours with horizontal stripes.

Aneel Bhangu

THE KNOWLEDGE

GAMES / BOOKS / GADGETS / TOYS

FOR CONNOISSEURS OF KIT AND SAVANTS OF STUFF

A Guide To The Olympic Games And London 2012

Price: £9.99

Get it from:

www.pen-and-sword.co.uk

It's not exactly light bedtime reading and, at full price, hardly something you'd choose over the latest George RR Martin novel. But Maurice Crow and Juliet Morris's guide to this year's Olympic Games could have been invaluable to our efforts to score top marks on our PE GCSE theory. It's also rammed with facts and figures – so great for keen quizzers – but with only a pathetically slim couple of chapters dedicated to the 2012 event and the rest a history of the Olympics, we feel the title's more than a little misleading.

HOW IT WORKS

LONDON 2012

Twice before London has hosted the Olympic Games: in 1908, with the British Empire at its peak and in 1948, a very different, post-war landscape, both culturally and economically.

Proporta BeachBuoy

Price: £17.95/\$23.95

Get it from: www.proporta.com

While the BeachBuoy is designed as a waterproof bike mount for your phone, it's actually guaranteed to five metres (16 feet), so you could drop a BeachBuoy-ed iPhone in a swimming pool and it will stay safe. The idea is that keen cyclists can view their smartphone – for GPS or otherwise – through the case window, assured in the knowledge that two click seals and a Velcro strip are keeping any water out and your phone in a snug, safe place.

HOW IT WORKS

VELCRO

Velcro was invented by a Swiss engineer in the Forties, though it took many years to develop and it was only after NASA used Velcro in the Sixties that its popularity really rocketed.

HOW IT WORKS

CIRCUMAUURAL HEADPHONES

This type of headphones, also known as full-size, cover the ear, rather than sit on top (supra-aural) or inside the ear (earbuds).

HOW IT WORKS

LED

LED stands for light-emitting diode and these devices create illumination via electroluminescence rather than incandescence like normal light bulbs.

Skullcandy Aviator

Price: £150/\$190

Get them from: uk.skullcandy.com

There's been a notable increase in designer over-ear headphones in the last decade, with musicians launching their own line of high-end cans with a bling price tag to match. At £150, Skullcandy's Aviator headphones have a top-end price too, but the quality lives up to it. You don't get much in the way of special features, but you do get a pair of 'phones whose optic-inspired design both looks the business and fits very comfortably. In terms of sound, super-crisp stereo is delivered by the 40-millimetre (1.57-inch) enhanced audio drivers, so you can plug it into just about anything and whack the volume up without distortion, though we wouldn't use them in a library as noise cancellation is notably absent. The cans also fold into a neat little package, so make a great portable audio solution.



R1 Tabletop Radio

Price: £159.95

Get it from: www.ruarkaudio.com

If this is just a bedside radio with an alarm clock, then the Oliver Messel suite at the five-star Dorchester hotel in London is just a bedroom. This is a luxury radio, a high-end DAB digital beast encased in a beautifully designed chassis. Don't let the vintage styling fool you, the R1 contains all the features you'd expect from a modern radio, including a digital display and switchable, multiple audio inputs. It's surprising just how much welly the nine-Watt speaker can produce and with a smooth, rich quality that we associate with the best sound systems. Curiously, the dream white and midnight black options carry a £20 premium over our favourite finish – walnut – which, in our opinion, is much better suited to the character of this retro-chic bedside radio.



HOW IT WORKS

INTERNET RADIO

You can listen to any internet radio station in the world because they are streamed across the web rather than broadcast wirelessly.

Kisai On Air Acetate watch

Price: £99.27/\$159

Get it from: www.tokyoflash.com

Renowned for creating some of the most innovative and esoteric watches out there, Tokyoflash's latest model is notable at the very least for being distinctly less bonkers than some of its predecessors. It's stylishly put together and feels quite robust too, but apart from the minimal design, its key feature is the touchscreen, which flicks between the date, time, alarm and the backlight. It's a funky timepiece, which will go very well with your SuperDry coat.

Car Science

Price: £9.99/\$19.99

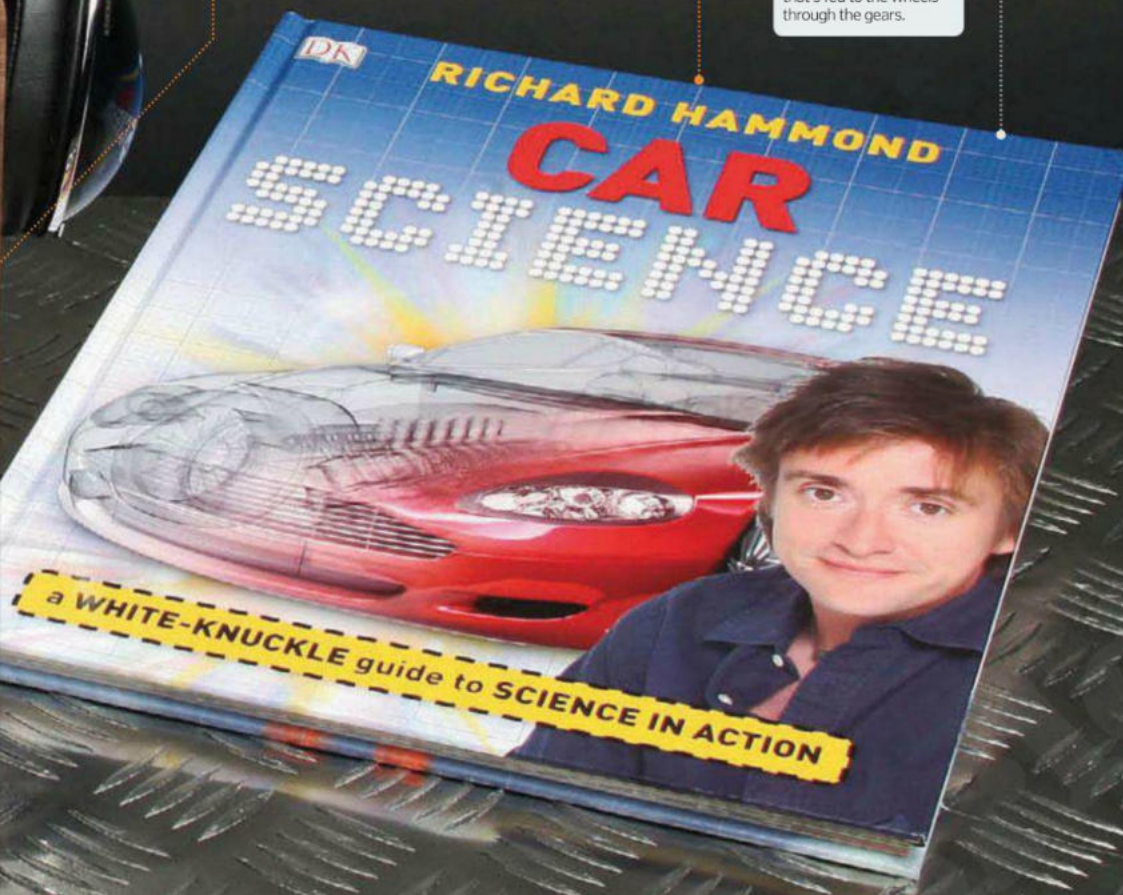
Get it from: www.dk.co.uk

Think about who would best endorse a fun car science tome for kids and Richard Hammond would probably be the first person who springs to mind. The most affable of the UK's *Top Gear* presenters put his face and foreword to this flickable, lightweight guide to the physics and mechanics of cars. It's jam-packed with facts and illustrations to keep a young mind interested and informed, and it's actually a rather handy reference for adults who aren't so clued-up on cars too.

HOW IT WORKS

BIKES VS CARS

The basic mechanics that drive a car are very similar to those of push bikes, with pistons acting like legs, providing a force that's fed to the wheels through the gears.



APPS OF THE MONTH

Brought to you by **Apps Magazine**, your essential guide to the best iPhone and iPad apps available on the Apple App Store

Day planning

Contact client



Work-divided

Team-meeting

iPhone: Clear

Price: £0.69/\$0.99

Developer: Realmac Software

Version: 1.1 Size: 7.2MB Rated: 4+



As you make your first few gesture interactions in Clear, you start to wonder if this app was secretly

made by Apple. It has all the simplistic beauty you associate with the computing giant, but this is indeed a third-party app. Developer Realmac has created an app that contains no buttons or tabs, just a clean set of to-do lists dedicated to an individual or specific area of your life, which are easily navigated by swiping, pulling and scrolling. Simplicity is at the heart of Clear's functionality, with no extra points or notes, just the headline of your reminder, which you can then swipe right to tick off or left to delete.

Verdict: ★★★★★

iPhone: Pinterest

Price: Free

Developer: Pinterest, Inc

Version: 1.5.1 Size: 6.3MB

Rated: 4+



Pinterest may have a legitimate claim to taking on Facebook and Twitter.

Based on the concept of allowing its users to interact with a personal pinboard, you can share anything in your life by 'pinning' all sorts of media to a virtual wall. It's a lot more personal than a Facebook poke or 'like'.

Verdict: ★★★★★



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Gaming peripherals

HIW trials three very different ways to play the same games

PROS
✓ Rammed with extra features
CONS
✗ Overpriced and wired-only

PROS
✓ High innovation and top quality
CONS
✗ Big chunk of change

HOW IT WORKS
EDITOR'S CHOICE AWARD
★★★★★

PROS
✓ An intuitive input device
CONS
✗ Limited game support

Razer Onza Tournament Edition

Price: £44.99/\$49.99

Get it from: www.razerzone.com

While Microsoft does, of course, manufacture an excellent line in gamepads, these first-party controllers lack the functionality and sensitivity required for some titles, particularly some PC games. That's the idea anyway, and the Onza TE is Razer's attempt to redress the balance. It features everything the Xbox controller has, with a few tweaks and extras. The action buttons are equipped with micro-switches for faster response time and more tactile feedback. There are two additional shoulder buttons that are also programmable and the analogue sticks can be twisted in either direction to adjust resistance. It sounds like it would give anyone's game a leg up, but in practice it doesn't work as well. While feedback on the 'Hyperresponse' buttons is deliciously precise, it doesn't afford any noticeable advantage and the adjustable analogues have a habit of sticking. The main problem is that the standard Xbox 360 controller is the result of over a decade of gamepad evolution – and it's also half the price of the Onza.

Verdict: ★★★★★

Razer Naga Hex

Price: £69.99/\$79.99

Get it from: www.razerzone.com

For PC gaming traditionalists, you don't have to compromise on your conventional mouse and keyboard setup to embrace modern PC gaming. The Razer Naga Hex is a natural evolution of the mouse peripheral. Its incremental design includes a 5,600dpi/3.5G laser sensor that gives it a one-millisecond response time plus Razer Synapse 2.0, a piece of software that enables you to reprogram buttons and flick between Razer peripheral profiles with a single button press. The Naga Hex's big selling point though is the sextuplet of buttons arranged in a hexagonal array which are controlled by your thumb. It takes a fractional movement to swap between the various buttons and, despite their extremely close proximity to one another, it's remarkably intuitive – the result of a superb piece of ergonomic design. It's a notably more effective solution than mapping actions to a keyboard and – you name the genre – the Naga Hex is a great fit. The price will raise some eyebrows, but it's a robust package that, in the long run, is well worth the investment in our opinion.

Verdict: ★★★★★

Razer Hydra

Price: £89.99/\$99.99

Get it from: www.razerzone.com

Motion control has been the exclusive domain of console manufacturers until now, with the Wii, PlayStation Move and, most recently, Xbox Kinect. So the Hydra is the world's first 'gaming grade' motion controller for PC gamers. It might seem like PC peripheral manufacturers have been a little behind in coming up with a motion-control solution, but this has been time well spent. The Hydra comes in two main parts: the base station and two remote Nunchuk-style controllers joined by a braided cable. The controllers are each equipped with four micro-switch buttons on the face plus a trigger and bumper. They fit comfortably in each hand and recharge on the base station, which is connected to your PC via USB. The magic happens when you start waving your hands around: the Sixense tech means the Hydra is capable of complete 3D control, so as well as moving along a flat plane you can also interact with the environment. It works every bit as well as a traditional controller; the only caveat is that the number of compatible games is currently 250, but this is growing all the time.

Verdict: ★★★★★

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TIE A TIE

Learn how to tie a Windsor knot and look super-smart at school or in the office

1 Stomach

First, wrap the tie around your neck so that the larger end is positioned over your lower stomach. Next, taking the large piece in hand, cross it over the front of the thin end.



2 Triangle

Once the large piece is crossed over, draw it up and under the small piece so it emerges through the triangular hole positioned between the shirt's collar and the tie. Once this is done, loop the wider section back down.

3 Loop

Pull the wide end under the narrow end from right to left and then loop it up and down once more through the triangular hole. Next tug on the large end so the semi-knot tightens.



4 Draw

Penultimately, you need to draw the larger end back across the narrow end from left to right and then loop it one final time through the triangular hole.



5 Slot

Lastly, slip the wide end through the knot in the front and pull it tight, drawing the knot up as you do so. Straighten if necessary.

FLY AN AEROPLANE

Discover how airline pilots fly commercial aircraft all over the world

1. TAKE-OFF

Getting an aeroplane into the air is all about the numbers. Having calculated the performance requirements of the plane based on weight, air temperature, airfield altitude and runway length, the engines are powered to the required thrust and, once the necessary airspeed is reached (VR), the pilot will pull back on the controls to lift off.

3. NAVIGATION

Just like a satnav in a car, lateral navigation is achieved using pre-programmed 'waypoints' which are imaginary markers at selected co-ordinates in the sky, at which you must alter direction, or heading. Aircraft must also navigate vertically, so at various points the plane must achieve specific altitudes. The on-board navigation systems offer high accuracy and reliability in modern aircraft cockpits.

2. CLIMBING

The initial climb phase begins as the aircraft leaves the runway and the vertical speed indicator (VSI) shows a positive climb rate. As key speeds and altitudes are reached tasks on the checklists are effected, such as retracting flaps. The engine power is reduced to the designated level, and the autopilot is normally engaged. The rate of climb will vary depending on fuel economy, local geography and how busy the airspace is.

Anatomy of a cockpit

Flying is all about managing the information presented to you by a host of instruments

Airspeed indicator (ASI)

Airspeed is what keeps you in the air, so knowing exactly how fast you are going is essential.

Vertical speed indicator (VSI)

This instrument tells you if you are climbing or descending, as well as how quickly.

Altimeter

Knowing your distance from the ground is essential even when you are too high up to see it.



**NEXT
ISSUE**
Change a tyre
Boil an egg
Juggle

4. CRUISING

An aircraft will spend most of the flight at a set speed and altitude that will maximise fuel economy and can be thought of as the 'motorway' part of the journey. This is the optimum flight level and it varies depending on both the vehicle weight and the atmospheric conditions, which means the aircraft should perform step climbs at regular intervals as using up fuel makes it lighter. Descending from cruise, the aircraft may be required to enter a holding pattern, while waiting for a runway to become clear, for instance.

5. LANDING

On direction from air traffic controllers, the aircraft may enter the downwind approach parallel to the runway, begin to lower flaps and turn to line up for landing. The landing systems will guide the pilot in both lateral and vertical navigation to ensure they are on the 'glide slope' to the runway. The landing gear is put down. The aircraft will be at approach speed (VAPP) until a few seconds before touchdown, when the pilot performs a 'flare' manoeuvre by pulling back on the controls just before landing.

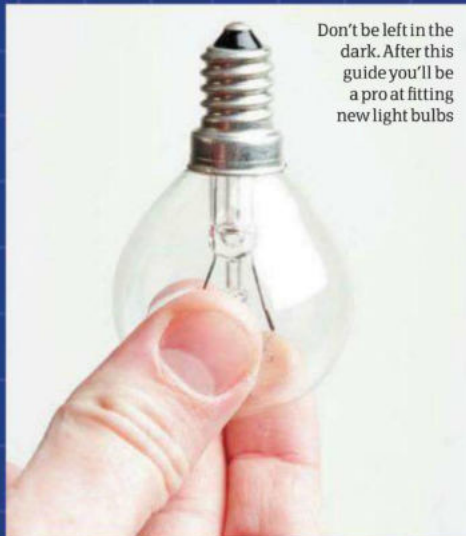
Artificial horizon
Displays your orientation relative to the horizon, which is useful at night, in fog or when near mountains.

Engine status display
To ensure safe flight and fuel efficiency it is important to keep a close eye on your engines with this instrument.

Disclaimer: Neither Imagine Publishing nor its employees can accept liability for any adverse effects experienced when carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

CHANGE A LIGHT BULB

Unsure how to restore light to your home after a bulb blows? Well, let these illuminating seven steps guide you...



Don't be left in the dark. After this guide you'll be a pro at fitting new light bulbs

1 Fuse box

First and foremost, be sure to kill the light bulb's power supply. The best way to do this is to cut all power by switching the red power button to off in your fuse box.

2 Cooling

Second, wait at least five minutes so that the bulb can cool down. Light bulbs get incredibly hot when in use and handling them immediately can lead to burns. Once cool, ensure that you are standing on a stable surface (such as a stepladder) when reaching up to the fixture.

3 Bayonet

Now it's time to remove the bulb, which can vary in operation depending on the type of mount - either bayonet or screw. For bayonet mounts, grasp the light bulb and push upwards gently while twisting anti-clockwise.

4 Screw

If, however, the bulb is a screw fitting, just grasp the bulb and repeatedly screw it anti-clockwise until it is free.



5 Clockwise

Next we can replace the bulb. Taking your new bulb in hand, slot it into the fixture and rotate it clockwise. Screw mounts simply require multiple clockwise turns, while bayonets require you to line up their

prongs with the fixture's holes prior to screwing.



6 Power

Once the new bulb is installed, restore power at the fuse box and then trial the light bulb by flicking its switch. If all has gone well, the room should now be illuminated once more.

7 Disposal

Finally, we must dispose of the old bulb, which shouldn't be thrown into a general waste bin. Instead, wrap the old bulb in the new one's packaging and place in a glass bin. Only certain bulbs are recyclable, so check.

TEST YOUR KNOWLEDGE

ENJOYED THIS ISSUE? WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ BASED ON THIS MONTH'S CONTENT?

- How fast was the Falcon HTV-2 travelling when it exploded?
A:
- In which year was the 'Plum Pudding' atomic model created?
A:
- How heavy is the ASUS Zenbook UX21E in kilograms?
A:
- In which year was Carl Sagan's book *Pale Blue Dot* published?
A:
- How big is the CV90120 tank's main cannon in millimetres?
A:
- What percentage of the world's terrain is desert?
A:
- How many orcas are currently held in captivity worldwide?
A:
- How tall was the statue of Zeus in the temple at Olympia?
A:
- Which Egyptian pharaoh is considered the main 'foreman' of the Sphinx's construction?
A:
- What is the standard human body temperature?
A:

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> ISSUE 33 ANSWERS

- 1.6 2. 2.048 x 1.536 3. 0.338
4. 1.750mAh 5. 500mn 6. 200
7. 236mph 8. 55 9. Tull 10. 03/1918



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We enjoy reading your comments every month. So keep us entertained by sending in your questions for the mag, comments on what you like/don't like, or any science-related news you want to share.

FANTASTIC PRIZE FOR LETTER OF THE MONTH!



WIN AN ANNUAL PASS WORTH £100

The fun and interactive INTECH Science Centre & Planetarium is offering the winner of our Letter of the Month a whole year's unlimited entry to the wonderful world of educational discovery at INTECH for four people (adults or children).

What are fingernails good for?
Quite a lot actually, if you scratch under the surface...



Could we use Earth's natural magnetism to produce power?

Letter of the Month

You spin me...

I was thinking the other day about energy sources. Then an idea sprung into my head: put a piece of magnetised metal inside a ring at the north pole of a magnet, and the piece of metal will spin, and a generator could be attached to create electricity. Think of it as putting a compass at the North Pole – they spin round and round. Would this idea work, and if so would it be a good energy source?

Andrew Gladders

HIW: That's a fair question, Andrew, but power from the Earth's magnetic field simply wouldn't be cost effective enough. The best way to extract it

would be to make a very long, superconducting solenoid (a wire coiled into a helix), such as the one found at CERN. But with only three-billionths of a volt per square metre, it would be much less cost effective than other forms of renewable energy. Also, this energy comes directly from the Earth's magnetic field and draining that could have cataclysmic consequences for the planet, although we would have to take a lot to feel the effects.

Win!
Annual Pass to INTECH Science Centre

Hair and there

I woke up one day thinking about nails (the ones on your fingers) and I wondered how could something that is the same material as hair look and feel quite different. That led me on to another thought: why do we even have nails? We have eyes to see, noses to smell and nails to... scratch people in fights? I'm pretty sure that's not what evolution intended them for, though, is it?

Sai Mun Wan

HIW: We take our nails for granted but they're not just a vestigial part of our evolution. They help protect the tips of our fingers and toes but, more importantly, they're a tool. They provide a precise grip in themselves, but also enhance sensitivity and movement precision by acting as a

counter-pressure. Human hair and nails are, indeed, both made of keratin. In fact the use of the protein for insulating hair, protective armour and weaponised as claws or talons is widespread in the animal kingdom, including the horn of the rhinoceros.

Life on Mars?

Could astronauts successfully land on the Red Planet and survive?

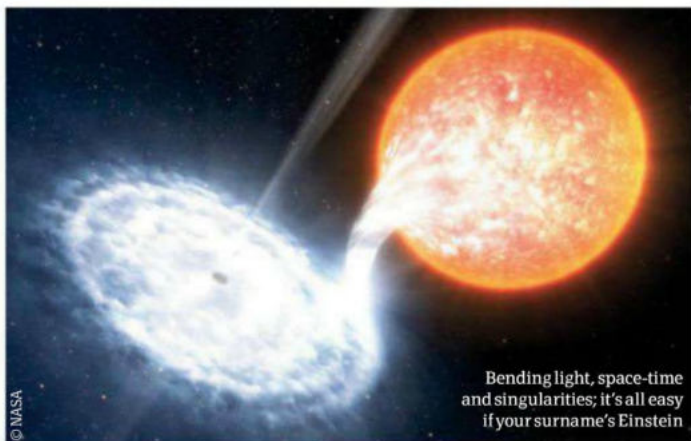
Susan Fielding

HIW: The surface of Mars is more hospitable to human life than that of the moon, which has no atmosphere. But that's not to say we could send an astronaut out there, pop the hatch, take a big gulp of Martian air and wander around the surface with no protection. Mars has an

atmosphere made mostly of carbon dioxide and a small percentage of nitrogen and argon. It has a surface pressure of 0.6 per cent of the Earth's at sea level and its temperature varies from -87 degrees Celsius (-125 degrees Fahrenheit) to -5 degrees Celsius (23 degrees Fahrenheit) during the summer. However, NASA does aim to put a man on Mars – suitably protected, of course – by the year 2037.

Faster than light

Hi, I was recently watching a science programme on television and it was explaining black holes. The presenter was saying that even light couldn't escape a black hole because the pull of gravity was so strong. So that got me thinking, wouldn't that mean that the mass



Bending light, space-time and singularities; it's all easy if your surname's Einstein

entering the point of singularity would be travelling faster than the speed of light (because light can't escape)? So if you could somehow create a black hole-proof capsule containing a person then that person would go back in time!

James Dahlgreen

HIW: The answer is actually pretty complicated, James – as you might expect! Essentially, light doesn't move any faster because of the curved space-time around a black hole. Depending on where you measure the speed of light from will give you different readings: from some distance away you might observe light to travel at a greater velocity when it enters a black hole, but if you jumped into your magic capsule and measured the speed of light from within the black hole, it might well appear normal.

Metal matter

■ I know how aluminium is the third-most abundant element on the Earth's surface and how it is found in bauxite, but what I really want to know is how it is mined...

Joe Bushby

HIW: Bauxite isn't a mineral in itself but a sedimentary rock filled with minerals including aluminium. Bauxite-rich seams are widespread across Earth, mined extensively in

Australia and Guinea. It's usually open-cast mined from a layer four to six metres (13-20 feet) thick just under the topsoil, or blasted out of the ground for deeper seams. Underground excavations make up 20 per cent of the world's bauxite production, with about five tons of bauxite creating a ton of aluminium.

A bloody business

■ I read we need iron to make haemoglobin, but what I want to know is how the iron enters our system and how haemoglobin is created?

Anshuman Saha

HIW: Iron is the most common element, by mass, on our planet and it can also be found in many everyday foods. Iron has many important functions in the human body but especially for making haemoglobin, the part of red blood cells that allows them to transfer oxygen. It's made in the marrow of our bones and once it's spent its oxygen, it's quickly replaced and sent to the intestines and spleen to be broken down. Several foodstuffs are naturally extremely rich in iron, such as red meat (particularly liver) and leafy green vegetables like spinach, while some cereals and breads are fortified with iron by the manufacturer.

What's happening on... Twitter?

We really love to hear from **How It Works'** dedicated readers and followers, with all of your queries and comments about the magazine. Here we pull together a varied selection of the most interesting tweets from the last month.

✉ Dan Burt

@HowItWorksmag

Did you know our moon is moving away from us at a similar speed to fingernail growth?

✉ Thomas

@HowItWorksmag

Is it possible to see the Sun and the moon in the sky at the same time (when there isn't an eclipse)?

✉ Linda Lum

@HowItWorksmag

I'd be in the Hummer H1. Though I'd switch the bright red for black :)

✉ Money4Machines

@HowItWorksmag

Can you lovely folks explain why the M4M office cat cleans herself for hours then rolls around on the dusty pavement?

✉ Fragrant Moments

@HowItWorksmag

Why does a smell seem to fade after you get used to it?

✉ Davsy

@HowItWorksmag

Had a sneaky read of a mate's mag. Had to subscribe. Just had my first issue – it's brilliant! Can't wait for the next one!

✉ Jason Castle

@HowItWorksmag

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